Financial Evaluation and Adoption Characteristics of Water Management Practices and Technologies in Eastern Canada

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By

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ABSTRACT

Primary agriculture and the agri-food sector contributed $112 billion to Canada's economy in 2017. Within Canada, Ontario and Québec are the two largest fruit and vegetable producing provinces. Irrigation and drainage practices are necessary to produce these high value horticultural crops. With an increasing population, and a decrease in water resources brought forward by climate change and competing uses from other sectors, there is a concern that water for irrigation purposes might be less readily available in the future. This situation can pose serious economic risks to agricultural producers and environmental risks to habitats and ecosystems. Farmers' adoption of improved water management practices or technologies can be both a mitigation of environmental impacts strategy and an adaptation to a changing environment. Across Canada, efforts have been made to develop and implement improved technologies and management practices, beneficial management practices (BMPs) that could be implemented with government help (such as through cost-share programs) or without them. Such BMPs are intended to minimize the negative impacts of agricultural production on the environment. For farmers to be favourably disposed to their adoption, financial gains are important. To understand the profitability of specific BMPs and factors that influence their uptake, it is important to examine these factors within the socio-economic and environmental context of interest.

Building on existing literature, this study aimed at filling certain research gaps. Namely, it was interested in understanding social, economic and environmental effects of improved water management practices and technologies in the context of Canadian fruit and vegetable production. Furthermore, this study aimed to contribute to the adoption of agricultural innovation literature selecting factors that foster or limit adoption of BMPs, together with building on the discussion on the importance of technology characteristics in the adoption process.

This study evaluated different irrigation and drainage practices (BMPs) within the context of three farms by comparing the situation when the BMP was adopted and that when it was not. To evaluate the financial desirability of investments, production budgets were developed for each of the scenarios. Results were converted into two indicators – net present value (NPV) and benefit-cost ratio (BCR), in order to assess the financial desirability of investments. The profitability of proposed BMPs was realized using three case study farms. The first one was a field grown tomato-

producing farm, located in Leamington, Southern Ontario, where under the baseline scenario surface drip irrigation was evaluated, and the proposed BMP was subsurface drip irrigation. A cranberry farm, located in Saint-Louis-de-Blandford, Québec represented the second case study. The baseline scenario reflected the effects of growing cranberries under a relatively wet water management strategy, without water table control. The BMP scenario represented a drier water table management strategy, where tensiometers were used to assess water needs. The third case study was a dry onion production farm, located in Saint-Patrice-de Sherrington, in Montérégie, Québec. The baseline scenario was that of no irrigation and no water table management, and the BMP scenario was sprinkler irrigation system together with the use of a tensiometer to help determine crop water needs.

The second major objective of this study was to understand regional growers' views on the proposed BMPs and the influence of different factors in their intention to adopt the proposed BMPs. To address this objective, regional producers were surveyed. There were 70 growers who completed the survey – 39 tomato growers, 19 cranberry growers and 12 onion farmers. To identify key determinants of adoption and perception of the BMP, two econometric models were used – a logistic regression model to explain adoption, and an ordered logistic model to determine influential factors in perception formation.

This thesis findings show that for all three commodities, the proposed improved water management BMP financially outperformed the baseline technology. The robustness of these results was reaffirmed through sensitivity analyses. In terms of environmental effects, it is more difficult to make more certain conclusions. One of the environmental effects of interest was GHG emission levels coming from the different BMPs. These data were collected only over two growing seasons and showed a large variability over the two periods. This resulted in a lack of statistical significance in the differences between each of the two water management systems. Findings from Edwards (2014), Grant (2014) and Lloyd (2016), showed that even though the differences were not statistically significant, on average, over two growing seasons the proposed BMPs produced less GHG emissions, these results need to be further verified.

The regional survey results showed that half of the sampled farmers were in favor of adopting BMPs, whereas the other half were not. However, when different farm groups were analyzed, the majority of onion growers were interested in the proposed BMP, cranberry producers were also predominately in favor of adopting sub-irrigation, whereas tomato growers were not interested in adopting a subsurface drip irrigation system. When compared to non-adopters, adopters had attained higher education levels, had a higher share of income coming from agricultural activities, and had less faming experience and primarily financial goals from farming. Adopters also had a higher share of sales coming from the selected crop (tomato, cranberry or onion) and owned a higher share of their farmed land than non-adopters own.

Producers perceived a BMP as a better alternative if it provided an added economic benefit, as well as reduced costs or added benefits to the local and global community. Farmers perceived the proposed BMPs as being profitable, but expensive, capable of improving crop yields and having the potential to reduce water use on their farms. Related to BMPs perceptions, several differences were identified between adopters and non-adopters. When compared to non-adopters, adopters perceived the BMPs as a better alternative than their current water management systems. BMPs were perceived as better alternatives if they were profitable, capable of increasing crop yields, reducing GHG emissions, reducing water use, fertilizer and chemical run-off from their farms, and benefiting the local community and society at large.

Economic factors predominantly influenced decisions of producers for adoption of the BMPs. Among these, influencing factors included BMP's capacity to increase yields, the profitability of investment, and ability to perform a trial of the technology. In addition to these factors, adopters also found non-financial factors like demonstrating environmental stewardship, important. Main factors identified as reasons to not adopt the BMPs, in the order of their importance were: market stability, profitability of investment, initial cost of the system, and the risk of investment.

Different combinations of factors can explain the likelihood of adopting the proposed BMPs. Based on this thesis, the models that best explain variations in likelihood of adoption should contain a mixture of farm, farmer and BMP characteristics related factors. Producers' perception that a BMP is better than the one they are currently using (degree to which a BMP is being perceived as a better alternative), explained most of the adoption outcomes (Variable ADOPT). A specialized grower, with higher education, who also perceived the BMP as a better alternative, and whose farming goals were mainly financial ones, was indicated to more likely adopt the proposed BMPs.

Given that one of the most important characteristics of a BMP in the adoption process is whether farmers perceive the BMP as a better alternative than the current practice, factors affecting this variable were identified using an ordered logistic function. Farmers with higher order farming goals (financial and lifestyle or social goals) and with higher education levels were less likely to find the alternative better than their current practice. Whereas, more specialized farmers perceiving the BMP as providing benefits to society, and who thought that making best use of scarce resources is important, along with the belief that the proposed BMP would reduce water use on their farm, were more likely to perceive the practice as a better alternative.

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DEDICATION

To my parents,

Irina & Stefan Bogdan

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CHAPTER 1. INTRODUCTION

1.1 BACKGROUND AND PROBLEM DEFINITION

In Eastern Canada, irrigation and drainage practices are necessary to produce high value horticultural crops, such as fruits and vegetables. With an increasing population, decrease in water resources brought forward by climate change and competing uses from other sectors, the concern is that water for irrigation purposes might be less readily available in the future (Chiotti and Lavender, 2008; Government of Ontario Ministry of Environment, 2011; Council of Canadian Academies, 2013; Lemmen et al., 2008; Yagouti et al., 2006). This situation can pose serious economic risks to agricultural producers and environmental risks to habitats and ecosystems. To sustain both livelihoods and ecosystems, changes in the current agricultural practices, particularly in on-farm water management, are needed.

Climate change is expected to have an overall negative impact on water availability in Southern Ontario and Quebec. Average temperatures have increased and are projected to further increase in these regions (Chiotti and Lavender, 2008; Lemmen et al., 2008). Furthermore, annual precipitation levels have decreased in Ontario over the last decades (Tan and Reynolds, 2003), and are further expected to decrease (Chiotti and Lavender, 2008). In Quebec, some climate models show a reduction in precipitation levels, while other models indicate an increase. Experts suggest that even with an increase in precipitation, the regional water levels will not be balanced, because the increased precipitation is not expected to offset the corresponding increase in temperature or evaporation rates (Lemmen et al., 2008; Yagouti et al., 2006).

Furthermore, worldwide agriculture is one of the significant set of activities responsible for the increase in greenhouse gas (GHG) emission levels, which in turn, is likely to bring diminished soil moisture, and increase frequency of extreme weather events in the Northern hemisphere (Romero-Lankao et al., 2014). Recent studies have found that depending on the water management system used by agricultural producers, different results can be obtained in terms of GHG emissions levels (Jones et al., 2012; Edwards, 2014; Grant, 2014; Lloyd, 2016). Even though studies show promising results in terms of GHG emissions reductions through increased irrigation efficiency, there is still limited knowledge regarding the effect of agricultural water management systems on GHG emissions and their adoption by producers.

Canada is one of the world's largest GHG emitter on a per capita basis. In 2015, the country emitted 722 mega tonnes (Mt) of carbon dioxide equivalent (CO_{2}-eq) – an increase of 18% above the baseline year 1990 (Environment and Climate Change Canada, 2018). Under a scenario in which the status quo is maintained, it was projected that by 2030, Canada's GHG emissions will reach 815 Mt of CO_{2}-eq. Agriculture is an important contributor to the country's economy, but it is also a significant contributor to country's GHG emissions, accounting for 10% of the total emissions. At the same time, it is the highest contributor in terms of N_2O, accounting for 70% of the national balance and a significant contributor to the national CH_4 balance, with 27% of the Canadian total emissions (Environment and Climate Change Canada, 2018).

Under various international agreements, such as the most recent Paris Accord, Canada has committed to reduce its emissions by 30% of the 2005 emission levels by 2030. In other words, Canada pledged to reduce its emissions to 517 Mt CO_{2}-eq. by 2030. To meet the GHG reduction targets, the Government of Canada, together with provincial governments has developed the Pan-Canadian Framework on Clean Growth and Climate Change, where specific measures to meet targets are presented (Environment and Climate Change Canada, 2016). One of these noteworthy steps taken was the introduction of a carbon tax of $10 per tonne in 2018, which is set to increase by $10 per year to $50 per tonne by 2022. Another action taken was the dedication of funds to research. Under the Global Research Alliance initiative, Canada contributed funds to develop the Agriculture Greenhouse Gas Program in Canada. The purpose of this program is to undertake research into development of new technologies, beneficial management practices, and transferring of information in four areas: livestock systems, cropping systems, agroforestry, and agricultural water use efficiency (Global Research Alliance, 2018; AAFC, 2017a).

The agricultural sector can help support mitigation in different ways, such as by reducing emissions, increased retention (sequestration) of emissions, or by providing offsetting alternatives such as biofuels (Meyer-Aurich et al., 2006; Smith et al., 2008). More efficient water-use technologies and practices, improved application of fertilizer, and a reduction of application of chemicals are amongst some of the on-farm strategies for mitigating GHG emissions. On-farm adaptation strategies can also reduce producer's vulnerability in the face of climate change. With increased evidence that climatic conditions are changing in various parts of the world, mitigation strategies are no longer enough as climate change policy responses, and increased attention is being paid to adaptation strategies. In a broad sense, adaptation can be defined as: "responses by individuals, groups and governments to climatic change or other stimuli that are used to reduce their vulnerability or susceptibility to adverse impacts or damage potential." (Bradshaw et al., 2004). Water use management is an adaptive measure that can be adopted by producers.

While farmers can implement mitigation and/or adaptation strategies, for some measures, their uptake has, in the past, required governmental support. In the last decades, farmers, researchers and policymakers have explored different technologies and practices aimed at minimizing the impact of intensive agricultural production systems on water, land and air resources. Across Canada, efforts have been also focused on developing policies to address these environmental threats posed by agricultural systems. Agriculture and Agri-Food Canada (AAFC), together with provincial and territorial agricultural departments, has encouraged practices that provide environmental benefits or decrease environmental costs through cost-share programs, as one of the elements of the current Growing Forward Program, (AAFC, 2014b). Beneficial Management Practices (BMP) are an example of cost-share program instruments, through which farmers are encouraged, through economic incentive-based mechanisms, to choose improved management practices and technologies.

Agricultural producers across Canada, also acknowledge their responsibility to care for natural resources (Environics, 2006). This is a favourable factor for adoption of such BMPs but results in uncompensated on-farm costs and off-farm benefits, which could become inhibitors of BMP adoption. Past experiences and historical data on adoption of these BMPs, in the context of Canadian agriculture, confirm that while some agri-environmental practices (especially those showing positive economic outcomes) were adopted more rapidly and more widely, while others tended to be modestly adopted and with insufficient effects in reducing the degradation of the environment (MacKay et al., 2010; Eilers et al., 2010; Council of Canadian Academies, 2013).

1.2 KNOWLEDGE GAPS AND NEED FOR RESEARCH

A producer’s decision to adopt a new BMP depends on its financial feasibility and its capacity to outperform a practice or technology that is currently in use. However, studies of farm level financial effects associated with the adoption of improved water management practices in fruit and vegetable production in Eastern Canada are limited.

Considerable research efforts have been directed in the last few decades to understand farmer's decision-making process, particularly as it is related to adoption of improved management practices and technologies (Feder and Umali, 1993; Sunding and Zilberman, 2001; Prokopy et al. 2008; Baumgart-Getz et al. 2012; Knowler and Bradshaw, 2007; and Pannell et al. 2006). Due to this extensive body of knowledge, it is common knowledge that in order to understand this behaviour, one has to take into consideration not only the standard socio-economic characteristics of the farmer, but also more attention needs to be paid to the physical environment in which the decision is being taken, the characteristics of the of BMP that is being considered for adoption, together with the perceptions of farmers form about BMPs.

While agricultural producers' adoption decision making has been studied extensively in Canada by Bjornlund et al. (2009), Kulshreshtha and Brown (1993, 1994), Smith and Smithers (1992), Traoré et al. (1998), Crabbé et al. (2012) and Filson et al. (2009), these studies have not focused on fruit and vegetable production in Québec and Ontario. In addition, there are limited amount of studies in the Canadian context on the economic, social and environmental impacts of adoption of BMP leading to improved water table management in fruits and vegetable production in Eastern Canada.

Studies in the area of adoption decisions of agricultural innovations use predominately the Diffusion of Innovation Theory (Rogers, 2003), as their main conceptual underpinning. However, in recent years, there has been growing interest in connecting adoption decision-making to another theoretical model – Theory of Planned Behavior, used to explain human behaviour (Lynne, 1995; Reimer et al., 2012). This theory was proposed initially by Ajzen (1991), and later developed into the Reasoned Action Approach (Fishbein and Ajzen, 2011). It explains further the role attitudes play in the formation of a decision. Through this perspective, specific attitudes related to the agricultural innovations of interest are related to what influences behaviour, as opposed to general attitudes. Adesina and Zinnah (1993) emphasize the need to take into consideration agricultural producers' perceptions of technology-specific characteristics when studying adoption decision-making, an area of study that has received little attention.

1.3 PURPOSE OF RESEARCH

One of the main purposes of this research is to evaluate three distinct BMPs from two perspectives: private standpoint – profitability of investment at the farm level; and the social perspective (values these BMPs add to society's wellbeing). This is done through an evaluation of on-farm costs and benefits associated with the adoption of improved water management systems, in Eastern Canada. It focuses on three distinct production systems – tomato, cranberry and onion production, and on three distinct BMPs – subsurface drip irrigation, reduced water table management and sprinkler irrigation.

The current research is also concerned with understanding farmers decision-making process related to the adoption of improved water management systems in Québec and Ontario. It aims to identify determinants of adoption (factors that encourage farmers in the adoption process) as well as barriers to the process of agricultural innovations adoption. This research focuses on expanding the existing body of work in the area of agricultural adoption decision-making, by further identifying factors that contribute to the formation farmer's perceptions of the three specific BMPs. Lastly, this analysis allows for identification of policy needs, required for fostering an increased uptake of beneficial management practices or technologies in agricultural production systems. Advancing knowledge in this area has the potential to better inform policy makers and support the development of policies and programs that are efficient and effective and allow for an increase in overall social welfare.

1.4 RESEARCH OBJECTIVES

This dissertation has two main groups of objectives. The first group is related to the on-farm evaluation of the three distinct BMPs, one for each one of the studied farms producing tomato, cranberry and onion. The second group of objectives pertains to the development of understanding of farmers' decision-making process used for adoption of improved management practices and technologies. In the second group, the last sub-objective is related to identification of policy implications stemming from this study. All study objectives and sub-objectives are listed below:

- **Objective one: Quantification and evaluation of farm level effects associated with the adoption of proposed beneficial water management practices or technologies**
    - Quantification and evaluation of BMPs profitability, through farm level analyses;
    - Evaluation of social and environmental effects associated with the adoption of the selected BMPs; and,
    - Comparison of economic, social and environmental effects of the baseline and alternative BMPs scenarios.

- **Objective two: Identification of reasons and factors for adoption, as well as barriers to adoption of beneficial management practices or technologies**
    - Identification of reasons for adoption and non-adoption of beneficial management practices/technologies of agricultural producers;
    - Identification of constraints and conditions under which agricultural producers adopt these beneficial management practices/technologies;
    - Identification of factors and their importance in the decision to adopt selected BMPs;
    - Identification of the role played by perception on adoption of BMPs;
    - Identification of policy implications based on current research

1.5 RESEARCH AIM AND SCOPE

The aim of this study is to understand the farm-level effects of proposed BMPs together with their desirability among regional producers. The scope of the farm-level analyses is limited to three case study farms, and the proposed technologies and practices. These are as follows:

- Subsurface drip irrigation in field grown tomatoes, Leamington, Ontario;
- Reduced water table management using tensiometers in cranberry production, Centre-du-Québec, Québec; and,
- Sprinkler irrigation in onion and carrots production, Montérégie, Québec.

Furthermore, for understanding regional producers' perceptions of the proposed BMPs, the focus of this study was on three main areas -- tomato, cranberry and onion production. Producers were surveyed from Essex and Chatham Kent in Ontario, cranberry producers from Centre-du-Québec in Quebec, and onion producers from Montérégie, also in Quebec.

1.6 STUDY OVERVIEW

In the following chapter (Chapter 2) of the dissertation, background information for the industry is provided, in addition to the expected impacts of climate change on Ontario's and Québec's agriculture, together with a description of salient characteristics of tomato, cranberry and onion production. Chapter 3 presents the findings of the thematic literature review on the potential effects of climate change in Ontario and Québec and the implications for the regional agriculture, the role of beneficial water management practices and technologies as mitigation and adaptation strategies. Furthermore, this section of the dissertation expands on the different theories underlying the adoption process, together with methods used to model the adoption process. Chapter 4 explains the methodological approach of the dissertation, including details regarding research design, research areas, participants' characteristics, data collection procedures, characteristics of the sample, together with a description of approaches used for data analysis. Results of the analysis are presented in Chapters 5 (starting with the evaluation of on-farm costs and benefits associated with the adoption of the various BMPs.) and in Chapter 6 (factors affecting adoption of the said BMP or its rejection). In Chapter 6, results of modelling adoption decisions and perceptions are also presented. Recommendations for policy changes together with a summary of the dissertation are provided in Chapter 7.

CHAPTER 2. BACKGROUND

2.1 INTRODUCTION

Eastern Canada is one of the country's fruit and vegetable production hubs. Within this vast area, agricultural production is more geographically bounded. In Ontario, the southwest region is where most of Canada's tomato production takes place. Historically, the region benefited from suitable climatic, soil and socio-economic conditions, which were conducive to pursuing high value crop production. Recently, economic conditions have changed, for example, the primary tomato processor located in the region closed its facilities. Furthermore, there is increased evidence suggesting that environmental conditions are becoming a matter of concern for agricultural producers – climate change is expected to have a negative impact on water resources in the region (Chiotti and Lavender, 2008; Tan and Reynolds, 2003; Council of Canadian Academies, 2013; Lemmen et al., 2008; Yagouti et al., 2006).

Another important region for fruit production is Central Québec. Cranberry production in the region has seen a rapid expansion in the last decade. Suitable environmental conditions, including climatic and soil characteristics, together with water availability, are amongst the main factors enabling this industry's expansion (MAPAQ, 2018). In addition to those factors, the innovation of local producers has also been a key in the regional development of the cranberry industry. They transformed the production system, collaborated to establish new local processing facilities, expanded the market and steward the safe management of the environment (MAPAQ, 2018). However, more stringent environmental regulations, volatile international prices and climate change are also likely to impact this region's thriving fruit production (MAPAQ, 2018).

In addition to fruit production, Québec is also a significant vegetable producer. Montérégie in Southern Québec is where most onion production takes place. Even though a humid region, in recent years, because of increased variability in rainfall patterns, an increasing number of vegetable growers started relying on irrigation to fulfill the crops' water requirements.

Sustained agricultural production relies primarily on healthy and available natural capital. Water availability and quality together with soil productivity are vital factors in agricultural production. In the next section (Section 2.2) of this chapter, the importance of tomato, cranberry and onion production within Canada is discussed. This is followed by characteristics of their production in Section 2.3. In section 2.4, an overview of the status of Ontario's and Québec's primary natural resources used in agricultural production is provided. In addition, the status and the potential impact of climate change on these resources is also addressed. This section also includes an overview of production volume, area, yields, prices and local actors. A summary of the chapter is provided in Section 2.4.

2.2 IMPORTANCE OF STUDIED FRUIT AND VEGETABLES IN CANADA

Primary agriculture and the agri-food sector contributed jointly to 6.7% of Canada's GDP in 2017, totalling to a contribution of $111.9 billion. Furthermore, this expanding area of the domestic economy also employed 2.3 million people, which represents 12.5% of total national employment (AAFC, 2017b).

Within Canada, Ontario and Québec are the two largest fruit and vegetable producing provinces. In 2017, Ontario accounted for 44% of the total national production of field vegetables of 2,178,560 metric tonnes, followed by Québec, which accounted for 38% of this production. Across the country, field-grown tomatoes had the largest production share (22%), followed by carrots (17%), and dry onions (11%) (AAFC, 2018a). The farm gate value[1] of tomatoes was the second largest of all field-grown vegetables, totalling $110.1 million nationally, with $92.9 million in Ontario alone (Statistics Canada, 2019a).

Southern Ontario, southwest British Columbia and certain regions in Quebec, are important fruit producing provinces. Within Canada, apples – accounting for 41.5% of total marketed fruits, blueberries (19.3%) and cranberries (15.1%) are the top three produced fruits (AAFC, 2018b). Overall fruit marketed production dropped in Canada, by 17% (831,392 metric tonnes) in 2017, compared to 2016. The total national value of cranberry production, assessed using farm gate value is of $114.9 million, with Quebec totaling $64.7 million (Statistics Canada, 2019b).

[1] Farm gate value is the market value of a product minus transportation, marketing and other sale related costs.

Ontario's primary agriculture and agri-food sector accounts for 6% of the province's GDP, with a total value of $38 billion (OMAFRA, 2018b). This sector is also an important source of employment for people in the province, offering over 800 thousand jobs (Statistics Canada, 2018).

Canada produces 244,953 metric tonnes of dry onions, with Quebec accounting for 43% of this production, valued at $105.5 million (Statistics Canada, 2019a).

2.3 FRUIT AND VEGETABLE PRODUCTION CHARACTERISTICS IN ONTARIO AND QUEBEC

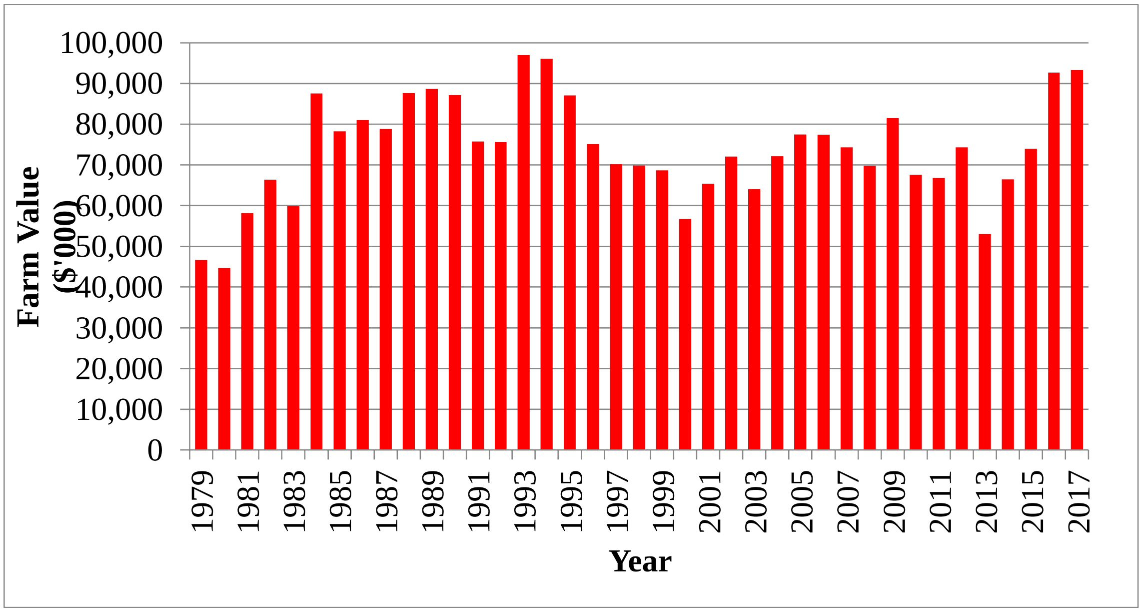
This section provides background information about tomato production characteristics in Ontario, and cranberry and onion production in Québec. Fruit and vegetable production sectors in these regions are characterized by providing salient facts regarding production volumes and areas, prices of commodities, descriptions of common cultural practices, and producer's water management practices and technologies.

2.3.1 Southern Ontario Tomato Production Characteristics

2.3.1.1 Production Volume, Area and Prices

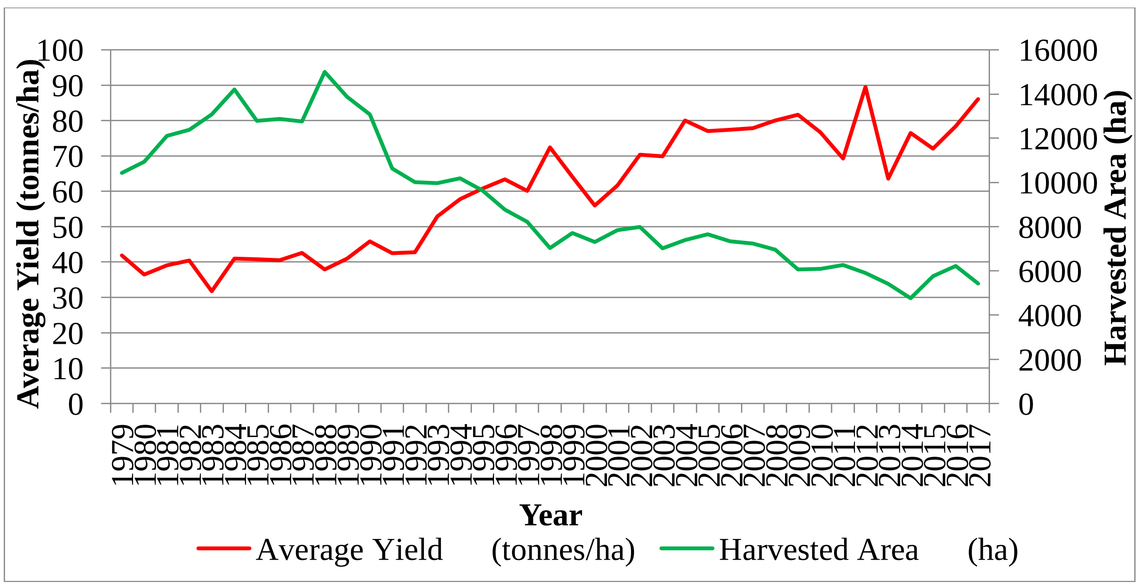
As previously mentioned, Ontario is the main producing region of field tomatoes in Canada. With a farm gate value of $93 million dollars in 2017, an increase of nearly 1% from 2016, shown in Figure 2.1, tomatoes surpassed other field vegetables – carrots ($41.3 million), peppers ($40.7 million) and sweet corn ($37.8 million) (OMAFRA, 2018a). Tomato production is concentrated in the southern part of the province, where 94% of the tomato production takes place (Statistics Canada, 2011). Within this region, there are two main production counties, Essex and Chatham-Kent that account for 29% and 59%, respectively, of the region's total tomato production (Statistics Canada, 2011).

Two trends are particularly noticeable in field tomato production in Ontario: One, production area has been reduced by half between 1979 and 2017; two, the yield per hectare (ha) has doubled. For example, in 1979 there were over 10,400 ha were under field tomato production, which reduced to only 5,426 ha by 2017. In addition, during the same period, average yields doubled, from 42 t/ha in 1979 to 86 t/ha in 2017, as shown in Figure 2.2 (OMAFRA, 2018a). Yield increases can be attributed to several factors, including: advanced knowledge regarding plant development and resource requirements, concentration of production into larger farms, specialized machinery and equipment, etc.



Source: OMAFRA (2018a)

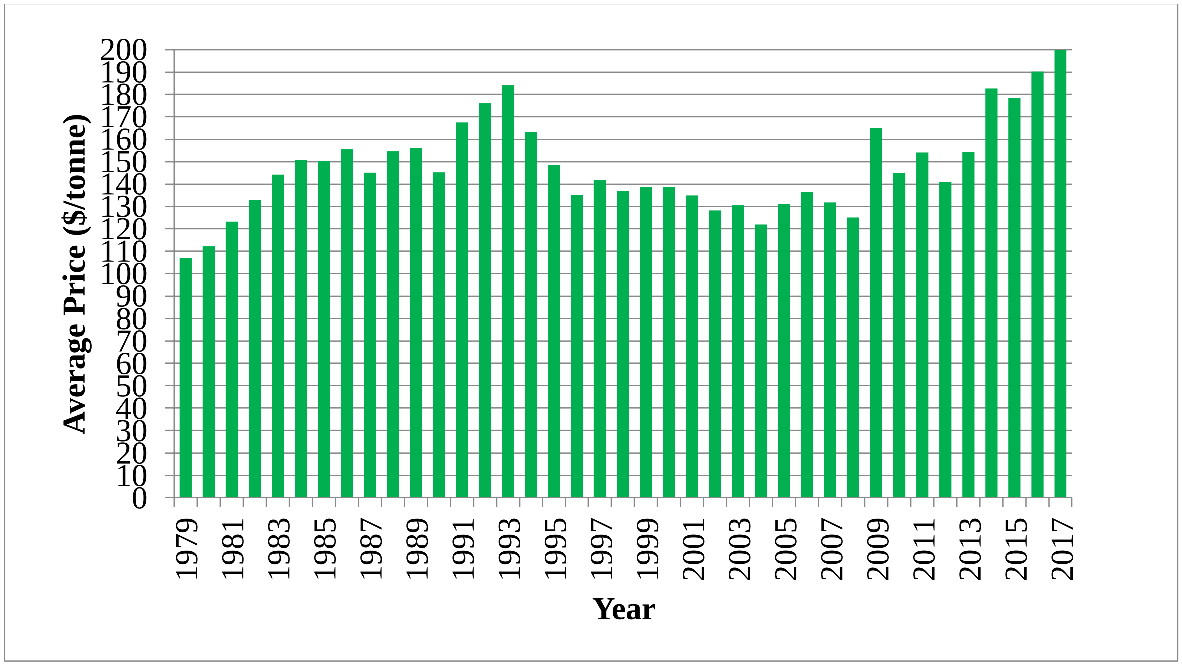
Figure 2.1. Trend in Tomatoes Farm Gate Value, 1979-2017



Source: OMAFRA (2018a)

Figure 2.2. Pattern of Tomato Production Area and Yields, 1979-2017

Historical data shows that while some oscillations in tomato prices occurred between 1979 and 2017, in the last decade a steady increase in average prices are noted, as shown in Figure 2.3. In 2017, the average price for field-grown tomatoes was $200 per tonne.



Source: OMAFRA (2018a)

Note: Prices are not inflation-adjusted.

Figure 2.3. Tomato Average Prices in $/tonne, 1979-2017

2.3.1.2 Regional Tomato Processors

Field grown tomatoes are predominately intended for the processing market, unlike tomatoes grown in greenhouses that are sold as fresh produce. In 2016, Ontario marketed 486,830 metric tonnes of tomatoes (OMAFRA, 2018a), out of which 464,264 metric tonnes were contracted by one of Ontario's main processors, totalling a contracted value of $55.7 million (OPVG, 2018). Ontario Processing Vegetable Growers Association (OPVG) is the organization that mediates negotiations between producers and processors for 14 vegetables, out of which tomatoes are the largest and most valuable crop they cover (Mussell, 2016).

According to a recent economic analysis of the fruit and vegetable processing industry in Ontario, the sector is struggling. This is reflected in diminished sales revenues – over the 2007 – 2016 period sales dropped from $3.4 billion to $2.6 billion, stagnation of a mature domestic consumers market (Mussell and Grier, 2017). Furthermore, Canada is showing a growing trading deficit with the main trading partner, the United States of America (U.S.A). In terms of Ontario's processed tomatoes trade, the deficit increased from $75-$100 million between 2008-2010, to $300 million in 2016, due to rapid increase in imports but also a slow decrease in exports (Mussell and Grier, 2017).

In recent years, the regional production went through significant changes. The HJ Heinz Company, one of the main regional processors, closed their processing facility located in Leamington in 2014. Some of its operations, including some contracts, were taken over by Highbury Canco Corporation. However, the number of agricultural producers whose contracts were maintained was significantly reduced. According to Ontario's Processing Vegetable Growers Association (OPVG) in 2014 there were 85 contracts (indicative of the number of agricultural producers but not the exact amount, since some producers have multiple contracts), a decrease by 40% in comparison to 2010 (OPVG, 2018). The processing sector is shared currently between seven processors: Conagra Foods Canada, Sun-Brite Foods, Highbury Canco, Harvest Pac, Nation Wide, Countryside, Thomas Canning, and Weil's (Mussell, 2016). In 2015 the prices ranged from $103/tonne ($114/ton) for paste, $112/tonne ($123.50/ton) for juice and $112.50/tonne ($124/ton) for whole pack – tomatoes peeled and packed whole (OPVG, 2018).

2.3.1.3 Tomato Producing Farms: Size and Distribution

In Ontario, in 2011 there were 1,422 tomato growers, whose produce was sold on the fresh market or for processing (Statistics Canada, 2011). The tomato growing area amounts to approximately 6,700 ha with the majority of enterprises located in Southern Ontario, covering over 6,300 ha. Regional statistics indicate that there are 542 tomato producers in Southern Ontario, with 100 of them located in Essex County, and 128 in Chatham-Kent. The average farm size within this region is between 20-30 ha (Statistics Canada, 2011). There is a large spread in the distribution of farms by size. At the provincial level over 50% of the farms are under 40 ha. This feature is also noted for Essex County, but the variation is higher in Chatham-Kent. The effect of intensification in agricultural production over time, has led to a decrease in the number of farms resulting in an increase in the farm size.

2.3.1.4 Characteristics of Tomato Production

Tomatoes are an important horticultural crop in Southern Ontario. They are produced predominantly in Essex, Chatham-Kent and Haldimand-Norfolk counties (LeBoeuf et al., 2008). They are produced either for the fresh market or for processing. Generally, field-grown tomatoes are grown for processing, unlike greenhouse grown tomatoes that are destined for the fresh market. This section focuses on tomatoes produced for processing. Tomatoes are processed into any one of the following: juice, ketchup, sauces, pastes, packed whole, purees, etc.

The growing season for tomatoes varies between 90-150 days and requires temperatures from 18.5 to 25ºC for optimal growth. The plant can be grown in a variety of soils; however, it performs better in light, well-drained soils (i.e., loams) with pH values between five and seven (slightly acidic to neutral). Requirements for N, P, K range from 100 to 150 kg/ha, 165 to 110 kg/ha, and 160 to 240 kg/ha, respectively (Jaria, 2013; Jones, 2007).

Water requirements across the growing season can vary between 200 mm -700 mm over a period of 90-120 days, extending from May to September. Peak water needs of nearly 6 mm/day are reached after the middle of the season (50-70 days). Soil texture influences the water holding capacity. As sandy soils have less water holding capacity than clay soils, they require different water management strategies.

Preparations for field tomato production start in the previous year, after harvest (September to November). At this stage, primary tillage is performed, and the beds are created with the use of a bed shaper. In spring, during the pre-plantation stage, the final preparations for tomato beds are completed, and herbicides and insecticides are applied together with a portion of the fertilizer. Transplanting of seedlings takes place in the first week of May, which is also accompanied by an application of starter fertilizer. Throughout the growing season, which usually spreads between May and September, there are several applications of herbicides and fungicides for pest control, together with additional fertilization, fruit ripener applications and multiple irrigation events, if required. Finally, tomatoes are mechanically harvested. Larger farms use a harvester together with two tractors with trailers, involving up to seven people – three drivers and four manual sorters (Miyao et al., 2008). The grower or contractor may transport the tomatoes to the processing facility.

2.3.2 Southern Québec Cranberry Production Characteristics

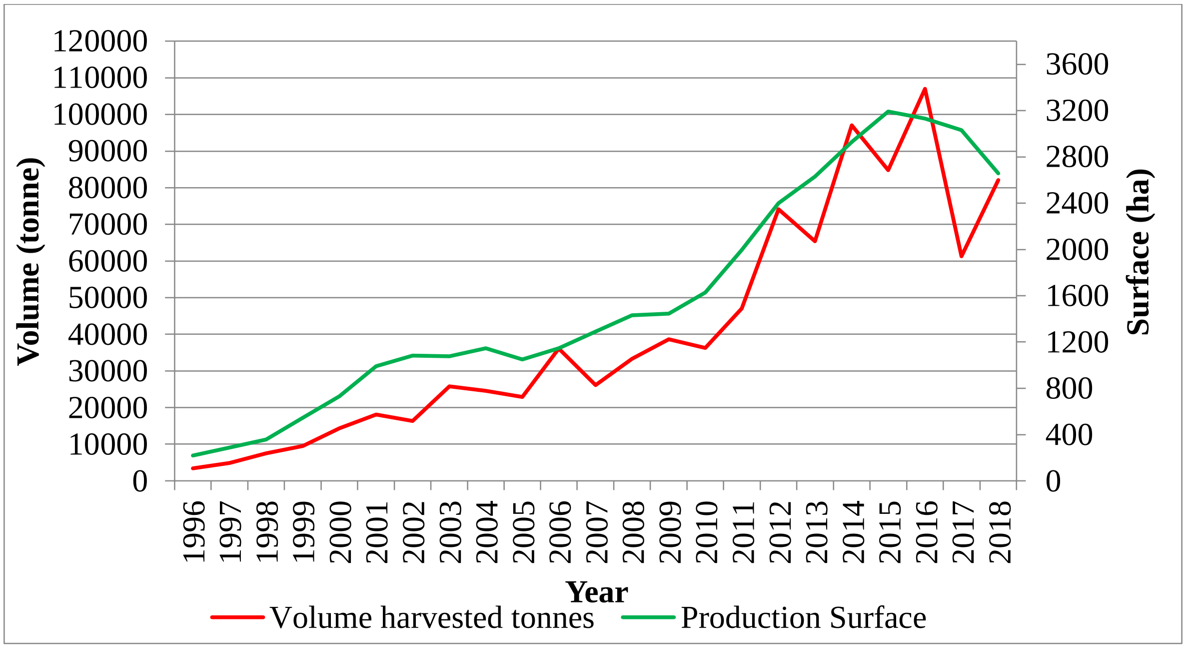
2.3.2.1 Production Volume, Area and Prices

On an international scale, in 2015, Canada was ranked second in terms of cranberry production – accounting for 28% of the total world cranberry production. U.S.A held 68% of the world production share, whereas Chile's market share was 4% (Deloitte, 2016). Canada is a net cranberry exporter, with exports totalling $124.5 million in 2016, and imports of only $6.1 million (MAPAQ, 2018). Québec is the largest cranberry producer within Canada, producing over 65% of the total production of 158,827 metric tonnes. British Columbia, accounts for nearly 29% of cranberry production (MAPAQ, 2018).

Centre-du-Québec is the largest producing region in the province, accounting for 90% of the provincial cranberry production. However, even within this region most growers are located in the rural municipalities of L'Erable and Arthabasca. The area dedicated to this fruit's production increased six-fold between 1996 and 2018. In 2018, 2,655 ha were under cranberry production in Quebec, compared to less than 400 ha in 1996 (APCQ, 2019). Figure 2.4 shows the production trends in terms of area cultivated and harvested volume in Québec, between 1996 and 2019.

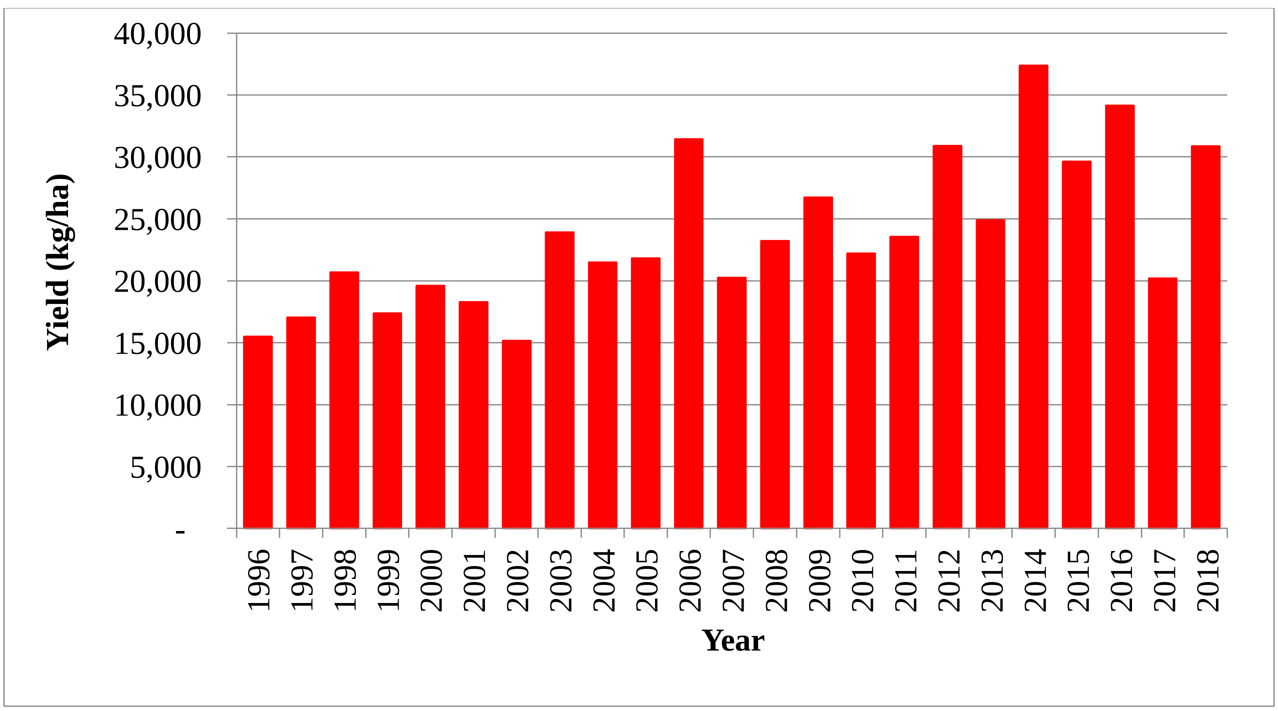
Altogether, in 2018 there were 78 growers producing over 82 thousand tons of cranberries (APCQ, 2019). In terms of farm gate values, this production was valued at over $64 million dollars in 2017 (Statistics Canada, 2019c). Over the last two decades, yields have been generally following an upward trend (Figure 2.5). The average yield in the province between 2008 and 2018 was around 27,000 kg/ha (APCQ, 2019).

One of the challenges faced by growers in recent years arose from the lower prices received for their produce. In the mid 90, the price of cranberries was $2.19/kg, which decreased to $0.10/kg in 2015 (Figure 2.6). Price received by producers vary depending on the processor, processing destination of the fruit, and the quality of the fruit, as a producer can receive a bonus of up to $0.018/kg, generally based on the colour of the fruit (M. Thomas, personal communication, December 2, 2014). The largest cranberry cooperative Ocean Spray influences cranberry prices at the international and regional level.



Source: APCQ (2019)

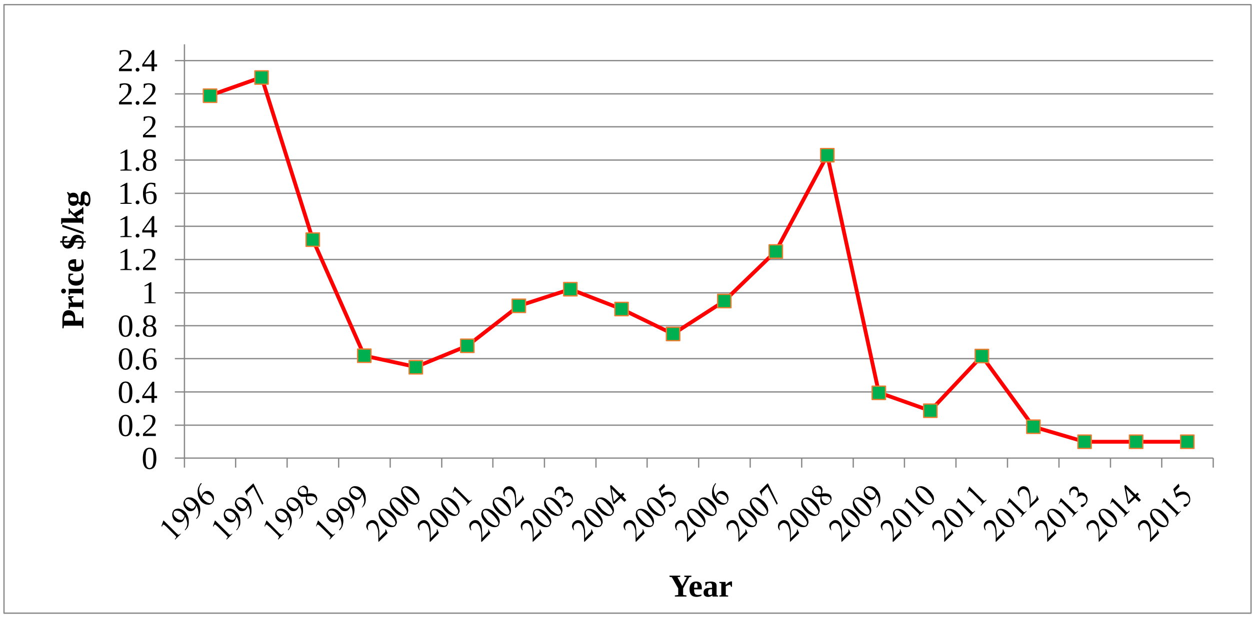
Figure 2.4. Trend in Cranberry Production Area and Harvested Volume, Québec 1996-2018



Source: APCQ (2019)

Figure 2.5. Growth Pattern in Cranberry Yields, Québec 1996-2018

While cranberry demand has increased in the last few years (in part due to research findings indicating additional health benefits, but also due to innovative industry marketing), cranberry prices have been plummeting. The accumulation of large cranberry stocks explains in part the observed price drop. When cranberry prices are low, processors are incentivized to increase their inventories above average, in anticipation of a price increase. However, this strategy had a negative effect on the prices both for growers and for processors (Alston et al., 2014)



Source: APCQ (2019)
Note: Prices are not inflation-adjusted

Figure 2.6. Historical Trend in Cranberry Average Prices, Québec 1996-2015

2.3.2.2 Farm Size and Distribution

Quebec farms reporting cranberry cultivation vary in size from only 1.5 ha to over 560 ha (4 to 1,400 acres). Approximately 59% of farms crop 160 ha, 37% are between 160 and 250 ha and only a small portion, more precisely 4%, are over 450 ha in total farm size (Statistics Canada, 2011). According to CRAAQ (2017) for every hectare under cranberry production, three additional hectares are required for additional farm infrastructure (i.e., drainage system, water reservoirs, etc.). CRAAQ developed a cost of production budget for a regional representative cranberry farm. From a total farm size of 195 ha, 65 ha were under production (CRAAQ, 2017). Even though the number of large cranberry producers is not large, their share of total cranberry production is high

(M. Thomas, personal communication, December 2, 2014). Entering the business of cranberry production can be prohibitive, due to the high initial investment required. CRAAQ (2010) estimated the cost of investment for establishing a cranberry operation of 50 hectares at slightly over 2 million dollars.

2.3.2.3 Regional Cranberry Processors

The cranberry industry in Quebec includes producers and processors. These two groups of actors contribute to the provincial economy, by bringing in a net contribution of $ 103.3 million and employment for 1,673 people (Deloitte, 2016).

Cranberries are predominantly consumed in the form of juice, which constitutes roughly 70% of the international market. However, there is a market for fresh and dried cranberry consumption as well – a segment of the industry that has seen growth in more recent period. In Québec, most of the cranberries are processed into dried fruit (nearly 60%) and the rest is processed mostly into juice concentrate (nearly 40%). In addition to that, a very small percentage is sold as fresh fruit (Poirier, 2010). Most of the regional production (more precisely 95% of the total) is bound for the United States' market. Approximately 70% of Québec's cranberries are processed in local facilities. The largest regional processors are Canneberges Atoka Inc., Fruit D'Or (also the largest organic processor in North America), Le Maison Bergevin and Canneberges L&S. Local processors sign contracts with the growers, of anywhere between 3 to 5 years in duration. The rest of the regional production is processed in the United States through the Ocean Spray Cooperative.

2.3.2.4 Network of Producers

Beyond growers and processors, there are other key agencies that provide support for regional cranberry production. The ACPQ is a growers' association and its main purpose is to represent the producers in the dialogue with the public, the government and other institutions. Another relevant institution is CETAQ, which is a voluntary agricultural and environmental club aimed at advancing sustainable farming through the implementation of best management practices among cranberry growers. The Cranberry Committee was established in 2001 and it includes the growers' association APCQ, Québec's Ministry of agriculture, and other organizations. Its objectives are to investigate the impact of the industry on the water resources and to guide actions that allow future development of cranberry production without compromising the environment.

Some examples of relevant issues to the committee are: risk of environmental pollution coming from pesticide use, and impact of pumping water from the nearby river Bécancour River – the main water body used by cranberry growers in the region (Handyside, 2003). The industry proactively tackled these issues by maintaining the effluent containing pesticide in on-farm basins for an additional period, to neutralize its effect on water bodies (Poirier, 2010). As for safeguarding the Bécancour River, water withdrawal permits are now required for new growers (Caron, 2009).

2.3.2.5 Characteristics of Cranberry Production

Historically, cranberries (*Vaccinium Macrocarpon Aiton*) have grown in wetland habitats in certain parts of North America. Now their commercial production has taken place in upland areas on sandy mineral soil beds, purposefully created with low-permeability and surrounded by water management systems that include water canals for drainage, dikes for water retention, and control structures for water level management.

Cranberry is a perennial plant (called lowbush). In Québec 75% of the fruits grown belong to the Stevens cultivar – a hybrid developed in 1950 (Roper, 2008). Worldwide this type of cranberries accounts for nearly half of total cranberry production (Averill et al., 2008). The plant requires well-drained and acidic soils (pH levels between 4 and 5) a cool climate, and good drainage and irrigation management (Poirier, 2010).

The growing season ranges between April and September. The cranberry plant is a low growing, trailing and with a woody vine, which spreads horizontally through runners. Vines form a thick mat, covering the entire surface of the cultivated bed (Sandler and DeMoranville, 2008). The runners send out uprights -- vertical branches, which can produce flowering (fruit bearing) and vegetative buds. By mid-June, the flowering period begins, and the plant requires pollination for better fruit yields. Berries develop between the end of June and beginning of July and require, on average, 80 days to ripen (Sandler and DeMoranville, 2008). Harvest usually takes place between September and October (APCQ, 2018).

Cultural practices related to cranberry production take place throughout the growing season. The preparation for the growing season begins in winter, soon after harvest. To protect the plants from frost damage, the fields are flooded with water in December, and later a layer of sand is spread on the surface of the bed. The sanding supports a healthy development of the plant, helps increase yields, and reduces pests (APCQ, 2018). In spring, floodwater is removed, and the plant leaves the dormancy stage. Sprinkler irrigation is used to protect the plant from frosting, but there are growers who also choose to flood the beds for a second time, between mid-April and mid-May. In the spring, herbicides and fertilizers are applied, and in May new vines can be planted. Throughout the summer, cranberries might require irrigation. Between mid-June and July, beehives are hired to help pollinate cranberry flowers. In the fall, the sprinklers can be used to avoid frost damage.

Cranberries can be either dry-harvested, or harvested in water, with most cranberries being harvested in water. During water harvest, the cultivated cranberry beds are flooded; the harvester rips the fruit from the vine that allows the fruit to float to the surface. The cranberries are gathered in a section of the bed and removed from the water with the use of a conveyor or vacuum hose (Sandler and DeMoranville, 2008).

2.3.3 Southern Québec Onion Production Characteristics

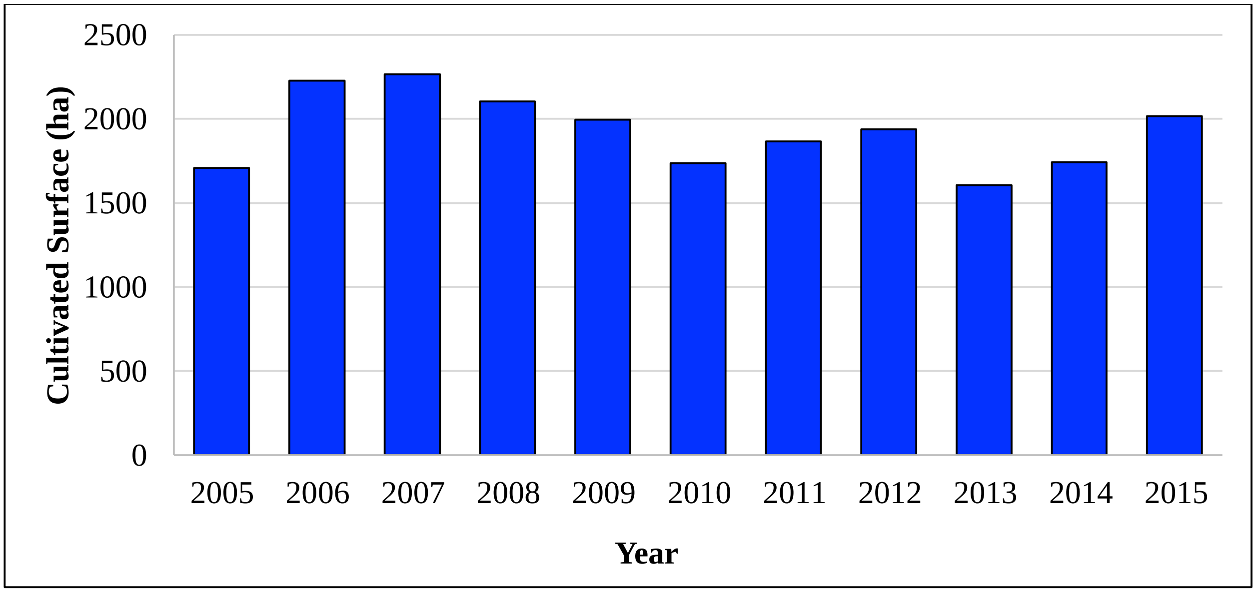
2.3.3.1 Production Volume, Area and Prices

Québec is the second largest dry onion-producing province in Canada. For the most part, dry onion production in Québec takes place in the Montérégie region, located in the southwestern part of the province. Mainly agricultural, the region is characterized by the clay soil lowlands of the St. Lawrence River. A long growing season, abundant rainfall and fertile soils have favoured the establishment of onion producing farms. According to MAPAQ statistics, 84% of total provincial onion production takes place in this region.

Dry onion production includes several types of onions: white, yellow, red, and Spanish. Approximately 40% of the produce grown is sold in the fresh market, another 10% of production is sold through the futures market, and the remaining 50% is kept in storage or exported (CRAAQ, 2008). By 2015, farm receipts from dry onion production in Québec were estimated to be worth over $28 million (MAPAQ, 2016).

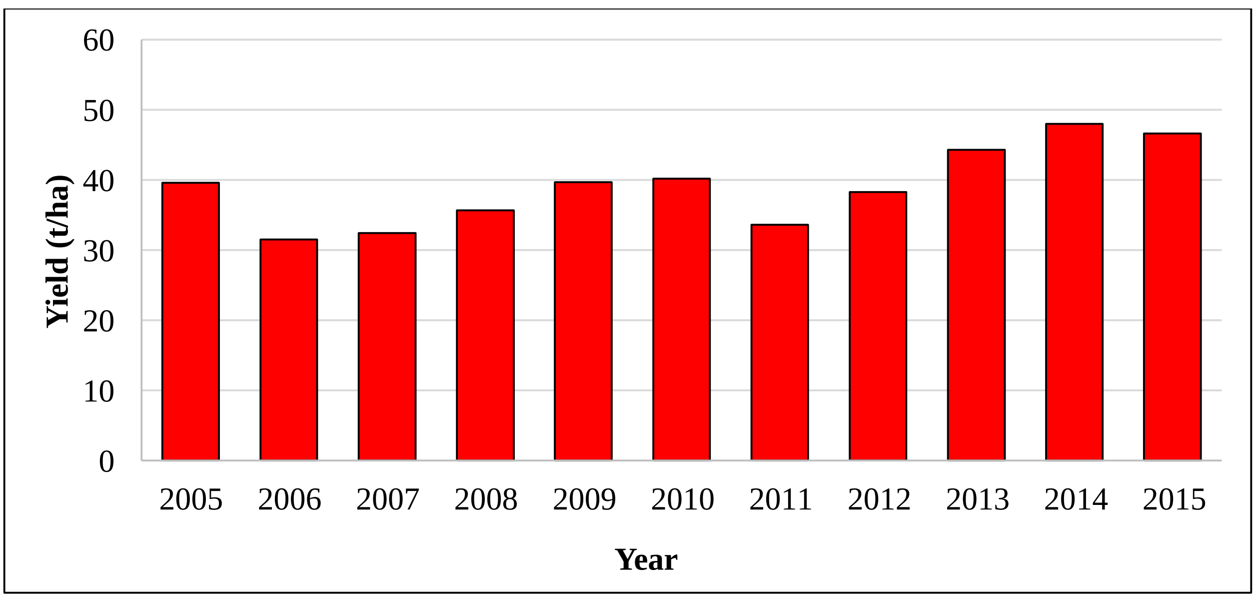
In the last decade, area under onion cultivation has increased slightly, while the number of farms has decreased. In 2005 there were slightly over 1,700 ha devoted to dry onion production; by 2015 this area grew to 2,015 ha -- an increase of nearly 18% (Figure 2.7).

In 2015, there were 332 onion growers in Québec, producing approximately 91,325 tons of dry onions. During the 2005 to 2015 period, the yields have increased from nearly 40 t/ha in 2005 to almost 47 t/ha in 2015 (Figure 2.8).



Source: MAPAQ (2016)

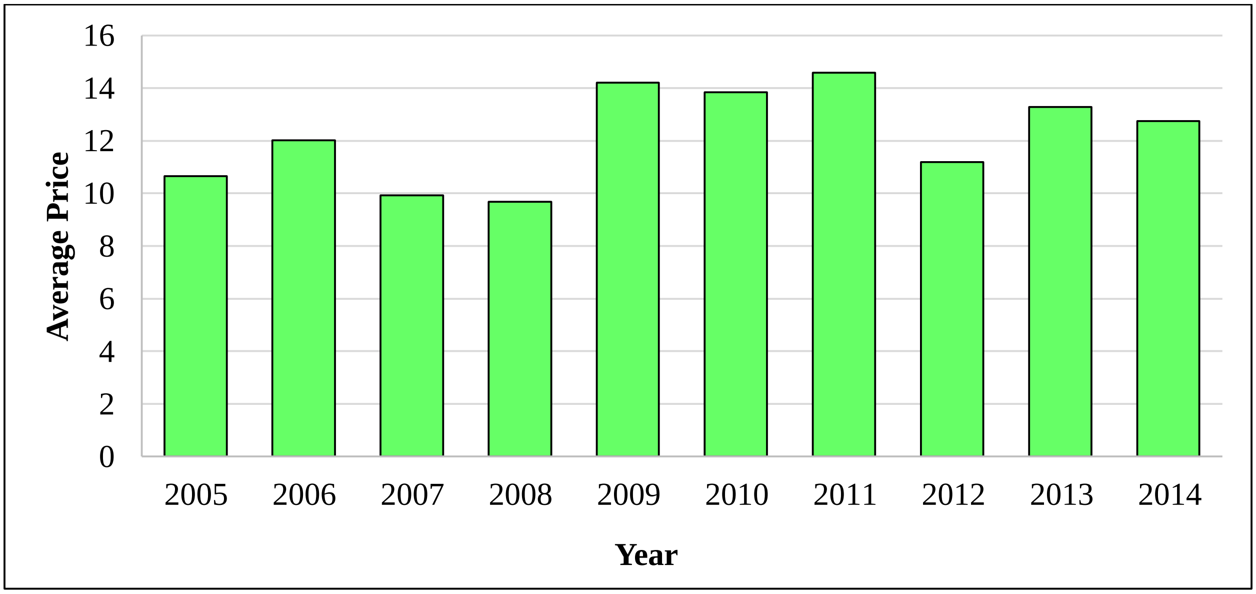
Figure 2.7. Surface Cultivated with Dry Onions (hectares), Québec, 2005-2015



Source: MAPAQ (2016)

Figure 2.8. Dry Onion Yield (t/ha) in Québec, 2005-2015

According to MAPAQ (2016), throughout the 2005-2015 period there were variations in dry onion average prices. In 2005, the average price was \$10.65/50lbs, equivalent to \$0.47/kg. In 2014 the average onion price increased by 18% to \$12.75/50lbs, equivalent to \$0.56/kg (Figure 2.9).



Source: MAPAQ (2016)

Note : Prices are not inflation-adjusted.

Figure 2.9. Dry Onion Price (\$/50lbs) in Québec, 2005-2015

2.3.3.2 Farm Size and Distribution

Majority of farms located in Montérégie (more precisely 66%) allocate less than 25% of their total farm area to onion production. In comparison, about 18% of the farms in this region allocate somewhere between 25-49% of their total farm area to onion production and 17% of all farms allocate 50% or more to onion production. In the Montérégie region 67% of the farms producing onions are under 20 ha in terms of farm size, while 21% of the farms have somewhere in between 50-109 ha. Only 11% of these farms are over 110 ha. For the most part across Montérégie, onion production takes place on organic soil (MAPAQ, 2016).

2.3.3.3 Characteristics of Onion Production

Dry onions are an important horticultural crop in Southwestern Québec. For the most part, they are produced for the fresh market. Marketed produce is categorized into size classes: as pre-packed (< 45 mm), small (45–57 mm), medium (57–76 mm), or jumbo (>76 mm). This crop is grown in different rotations, lasting between 2-3 years. The crop rotation can include either carrots, lettuce and/or potatoes (C. Turgeon, personal communication, February 19, 2016). Onions require fertile and well-drained soils, with loam soils being the most suitable for growth. They need up to 6 cm of water on a weekly basis, and a soil pH ranging between 6 and 8.4 (AAFC, 2014a). In Québec, the growing season for onions varies between 90-105 days, from the end of April to late August. After harvest, preparations are made for the following year's planting, by ploughing and tilling the soil (Wilson et al., 2011).

In Québec, the majority of dry onions are grown from seed at the end of April. Seeds are planted using a pneumatic precision seeder at a density of 35-45 seeds/meter, with row spacing ranging between 46cm - 62cm (AAFC, 2014a). Together with onion seeds, producers might plant barley seeds, which can serve as windbreakers, protecting the seedling and the soil from erosion. At this stage, an insecticide application is made in order to protect the seedlings. Producers, who irrigate, also use early spring to place their irrigation equipment in the field. The first fertilizer application generally takes place after the bed creation, and a second application is done later in the season around mid-June, once the plant is at least 15 cm high (Productions en Régie Intégrée du Sud de Montréal -- PRISME, 2016).

Plants emerge when soil temperature reaches 13°C and optimum growth occurs when temperatures range between 20 and 25°C (AAFC, 2014a). Weed control is realized either through tillage, before sowing, or by spraying throughout the growing season. At the end of the season, the irrigation equipment is removed from the field before the harvest begins. When 20-50% of the onion tops are down, onions reach harvesting maturity (Boyhan and Kelley, 2014). Two passes are made with mechanical onion diggers. The first one is for putting the onions on top of the cultivation beds, using a large horsepower tractor and a digger. The second pass is done to pick up the onions and convey them by a belt to a trailer pulled by a tractor, using a digger or a lifter. Two trailers support the harvester, and a crew on the digger sorts the onions (Wilson et al., 2011). After harvest, the onions are stored or packaged immediately. When the onions do not have time to dry in the field, they stay in a drier before being stored. Onions stored for long periods are treated with a sprout inhibitor (PRISME, 2016).

2.4 WATER USE AND MANAGEMENT BY COMMODITY

2.4.1 Water Use in Tomato Production

Compared to the rest of Canada, especially the Prairies, in Central Canada, a relatively small percentage of water resources are allocated for irrigation purposes. While the water extracted for agricultural purposes is not significant, it still represents the third largest water consumer in Ontario accounting for 20% of total provincial consumption. Municipal water supply is Ontario's top user, accounting for 38% of the total consumption, followed by the manufacturing sector (28%).

In Ontario 76% of the water extracted for agricultural use is consumed, meaning that this water is not returned to the source (De Loë et al., 2001). Across this area, for most part of the year, the rainfall received exceeds evapotranspiration. However, throughout the summer months of June, July and August, irrigation is generally required.

In Ontario, irrigation is mainly used for high value horticultural products, such as vegetable and fruit production. In Southern Ontario 43% of cultivated land is under irrigation, out of which 36% under vegetable production and 14% is under fruit production (Statistics Canada, 2011). Water sources for irrigation vary across the region. On-farm water sources can be rivers, ponds, dugouts or wells. In Ontario, producers rely mostly on on-farm water resources (i.e., ponds, reservoirs accumulating precipitations or fed from the municipal water ditches, etc.), since they fulfill 83% of their water needs. Of this total, 69% is obtained from surface water sources, while the remaining 14% from groundwater sources. Farmers supplement these on-farm sources with water from off-farm sources, such as municipal water, or water transported by a canal system or vehicle (Statistics Canada, 2013).

Irrigation technologies can be grouped into three broad categories: sprinklers (high and low velocity/volumes), micro (surface and subsurface drip), and surface irrigation (flood). In Ontario, the predominant technologies used are sprinklers, accounting for 70% of the irrigated area, followed by micro technologies that represent approximately 21% of the total irrigated area. The total area under irrigation in Ontario is 28,960 ha, with 1,045 farms using irrigation. Horticultural producers – fruits and vegetables producers (Statistics Canada, 2013) use most of the latter technologies.

Irrigation scheduling based on plants' water needs is crucial for optimal plant growth but also for water conservation purposes. In a survey of 34 southwestern Ontario irrigators, results provided by Dolan et al. (2000) results suggested that most of the respondents' schedule irrigation based on water needs, mostly assessed by measuring rainfall and soil moisture levels. However, Bernier (2008) notes that producers rely predominantly on their own experience to trigger irrigation, using the "feel and appearance" technique. Evidence suggests that this irrigation practice generally leads to an overestimation of water needs.

2.4.2 Water Use in Cranberry Production

Availability of water represents a critical factor in cranberry production. Irrigation in cranberry production serves multiple purposes. It can fulfill additional water requirements for the plant, alleviate heat stress, and provide frost protection. Beyond irrigation, water is also used for flooding during the harvesting stage and for protecting the plant over the winter. The cranberry growing season averages 150 days, during which time, average water requirements are 62 mm per month, with peak requirements of 102 mm/month under extreme conditions (Caron, 2009).

As the Centre-du-Québec, the region where cranberry production is concentrated, receives at least 95 mm in July – the driest month, irrigation is necessary. In addition to irrigation, water is used for flooding at the beginning of winter, in early spring, and for harvest. The cranberry basin or cultivation beds are flooded with water, reaching depths between 30 to 40 cm. Cranberry production is water intensive, it was estimated that on a yearly basis it requires 15,000 to 25,000 l/ha (Eck, 1976). However, not all water used is consumed. It was estimated that over half of it is recycled and reused or released back into the original water body.

Growers require a water reservoir with the capacity of at least 5,000 cubic meters per hectare, in order to meet their production needs (Caron, 2009 cited in Poirier, 2010). In Centre-du-Québec, growers depend on rainfall and snowmelt to refill their reservoirs. In addition to natural recharge, they pump water from the nearby surface water source, the Becancour River.

Water management in cranberry production is complex and relies on a diversity of technologies and practices. In cranberry production, drainage management and water table depth are closely linked to management of irrigation (Sandler et al., 2004). Most growers use a sprinkler system for irrigation purposes. The nozzles are located within the cranberry beds, a few centimetres above the ground, between 15 and 18 meters apart (Pelletier et al., 2015). Water travels from the reservoir – usually located at higher elevation on the farm, into the field by making use of gravitational force. While gravity moves the water from the main reservoir to the cranberry bed requiring irrigation, the sprinkler system receives water with the use of irrigation pumps.

Another method of irrigation used by cranberry growers is sub-irrigation. Sub-irrigation is a dual-purpose water management system that provides both irrigation and drainage. Additional water can be supplied through the same pipes that are used for drainage. The water table depth is regulated with the use of control structures. To maintain an appropriate water table depth, water is supplied under the surface, to provide ideal moisture conditions in the effective root-zone (Handyside, 2003). During the growing season and especially after heavy rain events, the drainage system becomes a very important component of the water management system.

Irrigated plots are also equipped with drains, good drainage of the cultivated beds helps prevent fungal development, salinity issues and decreased yields. Drainage is also used to lower the water table during spring snowmelt and after harvest. This is realized with subsurface drains and surface ditches available under and along each field (Roper and Vorsa, 1997). To manage water resources, some growers use tensiometers, which is a tool used to indicate the water available to the plant in the soil.

2.4.3 Water Use in Onion Production

Southern Québec is a humid region. The average annual rainfall is 760 mm. However, with rainfall events unevenly distributed, water can become a limiting factor at critical stages of plant development. Therefore, onion growers increasingly rely on supplemental irrigation to meet the plant water requirements. Based on experts' estimations, currently there are between 10-35% of onion growers who irrigate across Québec (LeBlanc and Turgeon, personal communication, February 19, 2016). Due to the shallow root system, onions are sensitive to water availability. Water becomes a critical factor at certain stages in onion production. For example, a lack of water at the vegetative stage can delay the bulbing, whereas insufficient water during the bulbing stage can affect the size of the bulb (LeBlanc, 2004). In sandy soils (found in Lanaudière, Capitale Nationale), producers need to irrigate to obtain good quality and yield. In organic soils (found in Montérégie), due to the higher capacity of the soil to retain moisture, the need for irrigation is less frequent, and thus it is less likely for growers to irrigate onions (LeBlanc, personal communication, January 26, 2016). In terms of water sources for irrigation, onion growers in Québec use a combination of sources, predominantly groundwater and on-farm reservoirs. Where irrigation takes place, most growers rely on the feel and appearance technique, when deploying irrigation (Leblanc and Turgeon, personal communication, February 19, 2016). The "feel and appearance" technique is a qualitative way of assessing soil humidity, by which the farmer uses a handful of soil to determine approximate soil humidity.

2.5 AGRICULTURAL GHG EMMISSIONS AND EFFECTS OF CLIMATE CHANGE IN ONTARIO AND QUEBEC

This section provides, in the first part, an overview of available research on agricultural GHG emissions coming from tomato, cranberry and onion production. In the second part, effects of climate change on the natural resources essential for agricultural production in Ontario and Québec are discussed.

2.5.1 Agricultural Production and GHG Emissions in Ontario and Québec

Agricultural fields can be both sources and sinks of GHG emissions. In terms of crop production, N_2O (nitrous oxide) emissions can be linked directly to application of organic or inorganic fertilizers, crop residue decomposition, and cultivation of organic soils. Indirect N_2O emissions are related to nitrogen leaching and runoff. In crop production, CH_4 (methane) emissions are associated with manure decomposition under anaerobic conditions. Carbon dioxide (CO_2) can be emitted through decomposition of crop residue and soil organic matter; however, it can also be absorbed through plant growth and storage in the soil as crop residues and soil organic matter (Desjardins et al., 2010). Soil moisture is one of the main factors affecting GHG emission levels coming from soils (Edwards, 2014; Schaufler et al., 2010; Smith et al., 2003). Agricultural management practices can influence the fluxes of these gases. Related to crop production agricultural management practices related to fertilizer type and applications, together with water management decisions, are likely to be the most influential in this regard.

Across Canada, there has been some success in reducing GHG emissions from agriculture; attributed to some degree, to changes in managerial practices, which allowed for increased sequestration of carbon. While in 1981 agricultural lands were a small carbon source (1.2 Mt CO_{2}-

$_{eq.)}$, in 2011 they became a carbon sink (-11.9 Mt $CO_{2\text{-eq.}}$) (Worth et al., 2017, p. 170). However, in Eastern Canada, GHG emissions are generally higher, more than 2,000 kg CO_2 equivalent per hectare, as opposed to less than 1,000 kg in Western Canada (Desjardins et al., 2010). Higher levels of GHG emissions are generally associated with intensive animal production, crop selection, and climatic conditions (Desjardins et al., 2010, p. 110). Other issues related to agricultural production systems in Ontario are increase in ammonia emissions levels, attributed in major part to livestock production, and use of nitrogen fertilizer. Ammonia has detrimental effects on the environment (affects air, water and soil quality) and poses direct risks to human health (Shepard and Bittman, 2010, p. 118).

There are few studies that have empirically quantified GHG emissions from field-grown tomatoes in the US (Kallenbach et al., 2010; Burger et al., 2005). In Canada, only Edwards (2014) has assessed GHG emissions from tomato production under surface drip irrigation and subsurface drip irrigation. The study contained data from two successive growing seasons. Results indicate that there was a slight reduction in GHG emissions in the case where the producer used a subsurface drip irrigation system. However, these results were not found to be statistically significant. On average, over the two growing seasons 2012-2013, GHG emissions were reduced by 16.8% under subsurface drip irrigation compared to surface drip irrigation, a yearly difference of 1.29 CO_2-eq t/ha (0.52 CO_2-eq t/acre) (Edwards, 2014).

Québec's agricultural GHG emissions have been on the rise in the last decades. Net GHG emissions have increased by 12% between 1981 and 2006 (MacKay et al., 2010). Cranberry fields can be a source of GHG emissions, mainly due to soils with high water beds (Grant, 2014), but also due to the flooding of the cranberry beds at harvest time. There is only one study (see Grant, 2014) within Québec that has empirically measured GHG emissions from commercial cranberry fields throughout the growing season. Grant (2014) conducted their study over the 2012-2013 growing season and found that emissions under a relatively wet treatment varied between 1.44 to 1.70 CO_2-eq t/ha, whereas for a dry treatment the range over these two years was from 1.28 to 1.77 CO_2-eq t/ha. This study showed that during the 2012 growing season, organic fields under a relatively wet water management regime produced 4% less GHG emissions when compared to mineral soils under a relatively dry water management regime. In the subsequent growing season, 2013, cranberry production under a relatively wet water management treatment produced 11%

more GHG emissions when compared to the dry treatment. Furthermore, results show that fields flooded for extended periods have higher emission levels than the ones that are flooded and quickly drained.

Another study by Lloyd (2016) assessed the GHG emissions from agricultural fields under onion production in Québec. This study evaluated the difference between irrigation and non-irrigation on three different soil types – mineral, medium and organic. Results show no statistically significant difference between the two treatments: irrigated or non-irrigated in terms of GHG emission levels. However, anecdotal evidence recorded for years 2012 and 2013 shows that during the 2012 growing season, organic fields under sprinkler irrigation produced 97% less GHG emissions when compared to dryland production. In the subsequent growing season, onion production under sprinkler irrigation produced 56% more GHG emissions when compared to dryland production. Over the two growing seasons 2012-2013, GHG emissions under no irrigation ranged were 2.22 and 2.31 CO_2-eq t/ha respectively, and for fields under sprinkler irrigation the emissions were 0.06 and 3.60 CO_2-eq t/ha, respectively.

GHG emissions from agricultural fields are often an indication of inefficiencies, which can be detrimental to both the producers and society at large. While in certain cases GHG emissions coming from agricultural fields are unavoidable, in other cases improved management practices can make a difference in reducing these emissions (Desjardin et al., 2010).

2.5.2 Effects of Climate Change on Water Availability Ontario and Québec

2.5.2.1 Ontario

Agricultural production in Ontario is primarily localized in the southern region of the province, surrounded by the Great Lakes. The basin of the Great Lakes is where approximately 25% of all Canadian agricultural production takes place, representing 60,000 farms and employing 1.4 million people (OMAFRA, 2016). With suitable climatic conditions, water availability, and fertile soils, high value horticultural production has thrived in this part of Canada. Within the last decade however, research indicates that Southern Ontario has begun facing increasing issues of water availability (Council of Canadian Academies, 2013). Already scarce water resources face increased demand from agriculture, municipalities, and industry. This competition and its associated shortage risks are likely to be exacerbated by changing climatic conditions.

Climate conditions are changing in southern Ontario and are bringing new challenges to agricultural production. In the last 60 years (1948-2006), the average annual temperatures have increased by as much as 1.4°C (Chiotti and Lavender, 2008). Climate projections indicate that by 2050 the annual temperatures will increase between 2.5°C to 3.7°C from the baseline 1961-1990 (Government of Ontario -- Ministry of Environment, 2011). Furthermore, in Southern Ontario, annual average precipitation has declined by approximately 225 mm in the last 20 years (Tan and Reynolds, 2003). Precipitation projections for the upcoming 45 years do not indicate large variations in the total amount of precipitation; however extreme rainfall events are expected to become more intense and more frequent, (Chiotti and Lavender, 2008).

These changes will have mixed effects on agricultural production. Tan and Reynolds (2003) indicate that in Southwestern Ontario, an increase in water deficits throughout the growing season, ranging from 80-275 mm, was observed over the last 20 years, with crops already showing yield decreases due to water stress. Water availability, given future climate conditions will be further limited. In addition to rainfall, fruit and vegetable producers depend on other water sources to supplement water needs in their production systems. The Great Lakes and groundwater reserves are additional resources on which agricultural producers rely. Water availability from these sources is likely to diminish under future climate conditions – declining lake levels due to evaporation and timing of precipitations, decreased groundwater recharge – and will likely increase the vulnerability of communities and activities reliant on these resources (Chiotti and Lavender, 2008). The issue of water quantity also raises important risks, beyond agricultural production, to in-stream flows needs for healthy aquatic ecosystems.

2.5.2.2 Quebec

Most of Québec's agricultural production takes place in the southern part of the province, within the St. Lawrence River Basin. Water sources for agriculture in Québec are diverse and include both surface water and groundwater. According to a recent report, the southwest part of the province is already experiencing pressure on water resources (Council of Canadian Academies, 2013).

As in the case of Ontario, Québec is also likely to encounter challenges in the agricultural sector, brought forward by a changing climate. In the southern part of the province, mean annual temperatures have increased up to 1.2°C, between 1960-2003 (Lemmen et al., 2008; Yagouti et al., 2006). Climate projections indicate that by 2050, the annual temperatures will have increased from between 2°C to 5°C in the southern regions of Québec, from the baseline period of 1961-1990 (Lemmen et al., 2008). Depending on the model used to project climate change effects on mean precipitation levels, there is a significant difference in their results, with some indicating a reduction of precipitation, while others indicate an increase. Experts suggest that even with an increase in precipitation, the balance will not be levelled in terms of water balance in the region. This is because the increased precipitation is not expected to offset the corresponding increase in temperature or evaporation rates.

Climate related changes are expected to hinder certain segments of agricultural production while helping others. Cranberry production is water intensive. In addition to this, most of the production in the province takes place in one region, making production reliant on the same surface water resources. To compensate for that and to ensure that a minimum in-stream flow remains intact, the Ministry of Environment requires producers to apply for pumping authorizations. This would likely alleviate some threats, but it does not extend to growers who had water withdrawal rights prior to the change in legislation (Caron, 2009). In the case of cranberry production in Centre-du-Québec, climate change could further exacerbate these issues related to water availability.

Currently, in the case of dry onion production growers in multiple regions of Quebec -- Lanaudière, Capitale Nationale and Montérégie among other. These regions are in southwestern Quebec, where as previously mentioned, water availability will be impacted by climate change. In Lanaudiere and Capital National, where there are mostly sandy soils, growers make use of irrigation thought the year, to ensure seedlings' proper development and desired yields and size. In areas where predominant is the organic soil, Montérégie, approximately 50% of the growers use irrigation, with most producers only using irrigation less frequently throughout the year (LeBlanc, personal communication, 2016).

2.5.3 Effects of Climate Change on Water Quality in Ontario and Québec

Ontario

Besides water quantity issues, the region is likely to face water quality challenges as well. Increased use of agricultural inputs (i.e., fertilizers, pesticides, etc.) help enhance the productivity of agricultural systems. However, overuse or inefficient use of these chemicals is one of the most common causes of damage to water resources worldwide. Surpluses of nitrogen, phosphorus and pesticides in the soil can pose enhanced environmental risks, due to possible leaching into ground waters or by reaching surface water bodies through runoff (De Jong et al., 2010, p. 80). Transportation of these surpluses into water resources diminishes water quality. Some of the most common effects associated with water contamination by nitrogen are, eutrophication (i.e., affecting aquatic life) and increased human health risks (i.e., drinking water issues).

In Ontario, the risk of water contamination by nitrogen has shown an upward trend. While some success was achieved in diminishing the risk of water contamination by phosphorous, southwestern Ontario shows increasing risks of pesticide contamination. Filson (2004, p. 19) explains that increased agricultural intensification in Ontario’s horticultural sector has raised increasing concerns in terms of water quality. This prompted local governments and agencies to work together with agricultural producers to find alternative practices to reduce runoff of nitrates, phosphates, pesticides and microorganisms.

Québec's risk of agriculture-related water quality issues due to agriculture has increased. According to Eilers et al. (2010, p. 200), during the 1981-2006 period, the province had a high to very high risk of water contamination by nitrogen due to agricultural production-related runoffs. While the risk of contamination by phosphorous was assessed to be lower, it was still categorized as being moderate to high. Another issue related to water quality is the increased risk of contamination with pesticides. This risk was increased in the southeastern region of the province, where predominantly fruits and vegetables are being produced (Eilers et al., 2010, p. 200). An assessment was made by CETAQ in collaboration with Ministère de l’Agriculture, des Pêcheries et de l’Alimentation du Québec (MAPAQ), to characterize effluents coming from cranberry farms (Caron, 2009). The concentrations of fertilizers were found to be below the threshold required for healthy aquatic ecosystems; however, throughout the harvest period, due to flooding of these fields, an increase in P and N concentrations were measured (Caron, 2009). In Centre-du-Québec, approximately 90% of farms have closed water circuit water management system in place (Caron, 2009), which has a positive effect on water quality.

2.5.4 Agricultural Production and Soil Productivity in Ontario and Québec

Soil erosion poses significant threats to sustainability of agriculture by negatively affecting soil fertility, ultimately affecting crop yields and profitability of agricultural production systems. Even though improvements have been made, in 2006 the Province of Ontario with the largest percentage of cultivated land with high levels of soil erosion risk (Lobb et al., 2010). Intensive tillage practices in the region are one of the reasons for this decrease in soil quality. However, soil water erosion was the main factor causing the loss of topsoil in Ontario. Soil water erosion is also associated with off-farm negative environmental effects. Surface water contamination with nutrients and pesticides, water turbidity, and sediment build-up in waterways, are among a few of the issues associated with agricultural soil water erosion (Lobb et al., 2010, p. 46).

Soil organic matter is one of the indicators used to assess soil health. Declining levels of organic matter in the soil can increase its vulnerability to erosion, which can diminish soil fertility, and therefore decrease yields. In Ontario, a large decrease in the soil's organic carbon has mostly been associated with past high levels of soil erosion (McConkey et al., 2010, p. 54).

Soil moisture, or water contained in the soil, is an important factor for agricultural production. It is a major factor determining plant growth. If the moisture content of a soil is optimum for plant growth, plants can readily absorb soil water. Soil water dissolves salts that make up the soil solution and is an important medium for supplying nutrients to growing plants. The IPCC report (see Romero-Lankao et al., 2014) has noted that an increase in the GHG concentrations is associated with reduced soil moisture in the Northern Hemisphere; thus, soils with a lower water-holding capacity (i.e., sandy soils) will be more sensitive to climate change. This is a potential threat to agricultural production in Southern Ontario, where soil water availability is likely to decrease by 30% in the summer and fall (Chiotti and Lavender, 2008). Tomato and cranberry production take place mostly on sandy soils, which means that these agricultural production systems can be at increased risk in the face of upcoming changes related to soil moisture.

2.6 SUMMARY

In this chapter, the economic importance (within Canada) of tomato, cranberry and onion agricultural production were discussed. Ontario is recognized for having the largest share of field grown vegetable production within Canada, with tomatoes topping the ranks. Quebec is a countrywide leader in terms of cranberry production. Furthermore, this province accounts for 43% of the national dry onion production as well. In the second part of this chapter, characteristics of production are described for each one of the commodities. Tomato and cranberry production are associated with large food processing industries, both in Ontario and in Quebec, as most of these commodities are intended for this market, and only a small share goes towards the fresh market. Water use for irrigation purposes and the on-farm management of water are discussed as well in this chapter. Tomato and cranberry production rely heavily on supplemental water, whereas dry onions are only sporadically irrigated. With changes in rainfall patterns, increased temperatures and increased loss of soil moisture projected, producers in these high value crop productions are expected to rely more on supplemental water for irrigation. These issues were discussed in the last section of this chapter.

CHAPTER 3. LITERATURE REVIEW

3.1 INTRODUCTION

This chapter presents a summary of the thematic literature review. The first section (Section 3.2) discusses the potential role of farm-level adaptation, together with the role of beneficial water management practices and technologies as adaptation strategies. In the second part of this chapter, approaches to farm level evaluation of BMP adoption are presented (Section 3.3). Following this, Section 3.4 discusses dimensions of adoption decision-making, by starting with theoretical frameworks used to guide this research. Furthermore, determinants of adoption, together with reasons and conditions that enhance adoption are presented, by summarizing the scholarly literature on these issues. The next section broadly describes policy tools, with emphasis on Canadian agricultural policy tools used to support the adoption of BMPs. The chapter ends with a synthesis of findings, and identification of knowledge gaps in the literature.

3.2 CLIMATE CHANGE ADAPTATION AND B.M.P. ADOPTION

BMPs are single practices or a bundle of practices, which have been scientifically proven to reduce the adverse effects of agricultural production systems on natural resources (air, water, soil, etc.), while ensuring a farm's economic viability (Klimas and Weersink, 2006). Others describe BMPs as a means of increasing agricultural production of ecological goods and services (Trautman et al., 2012), or as practical and cost-effective methods used for minimizing environmental impacts (Council of Canadian Academies, 2013). Agricultural BMPs are defined in the literature in various ways, but most definitions have several elements in common: environmental and economic considerations and their interdependencies.

BMPs are developed by farmers, researchers, agribusiness experts, and government, and belong to a comprehensive list of categories, including, but not limited to, legal issues and conflict prevention, environmental risk management, and the interaction of potential impacts of different alternatives. BMPs can be designed specifically for different production systems and for particular regions (Klimas and Weersink, 2006).

In Ontario, the provincial Ministry of Agriculture and Food (also called Ontario Ministry of Agriculture and Food and Rural Affairs or OMAFRA in abbreviation) implements cost-shared programs through the Ontario Soil and Crop Improvement Association (OSCIA). The OMAFRA recognizes six categories of BMPs focused on protecting Ontario's natural resources: environment and climate change adaptation, animal and plant health, market development, labour productivity enhancements, assurance systems (food safety, traceability, animal welfare and weather risk mitigation), business and leadership development (OSCIA, 2016).

Québec has the same categories of cost-share program; however, their agri-environmental program is delivered through MAPAQ's local advisors (MAPAQ, 2017). Technologies and practices addressing water quality and quantity issues are included under the climate change adaptation category. There are multitudes of BMPs that can be adopted by farmers to better manage water resources. These include practices (irrigation scheduling, improved soil moisture testing techniques, etc.) as well as technologies (i.e., drip irrigation systems, subsurface irrigation system, controlled drainage, etc.). All these measures affect water quantity and/or quality. Most BMPs are generally designed for a particular purpose. They can, for example, be implemented to increase the quality or quantity of a certain natural resource, but more often, it is noticed that their adoption influences several natural resources, providing multiple benefits (i.e., improved irrigation timing can reduce water use, energy use and reduce fertilizer run-off).

Farmers' decision to adopt or not to adopt a certain BMP is based on a multitude of factors, described in Section 3.5.4 of this chapter. However, some of the most important factors among these are financial feasibility of the investment, duration of payback, and the initial amount needed for the investment. Identifying and quantifying the on-farm effects of a certain BMP adoption is one of the primary steps in providing agricultural producers with the information needed to consider a certain BMP as a viable alternative. Financial farm level analyses provide the appropriate techniques to evaluate costs and benefits associated with a BMP adoption. In the next section, an overview of techniques used to perform a farm level analysis is provided, together with a description of steps involved in undertaking such an analysis.

3.3 FARM LEVEL ANALYSIS

Agricultural production systems represent a complex array of factors that are highly interrelated and develop feedback mechanisms (Dent and Anderson, 1971). The system can be disaggregated into biophysical, economic and social subsystems at the farm level. Agricultural producers manage agricultural systems with the purpose of achieving their goals, which can vary from increasing the farm's profits to increasing leisure time (Boehlje and Eidman, 1984). Over the years, a multitude of methods and approaches has been developed to perform farm level analyses. The following section describes the characteristics of various approaches and techniques used for farm level analyses.

3.3.1 Comparison of Approaches to Farm Level Analysis

3.3.1.1 Deterministic and Stochastic Models for Farm Level Analysis

Analysis of agricultural production systems entails the development of a model of the target system (in this case the farm) to make the task manageable. A model can be defined as a simplified version of the real agricultural system (Dent and Anderson, 1971). Characteristics that are carried in the model are the ones that are relevant to the scope of the analysis (Mugido, 2011). Therefore, a model is a projected viewpoint of the researcher or developer of the real system, including blurring the parts of the reality that are irrelevant to the analysis. It does so without compromising its capacity to provide adequate insights. Models are characterized as either **deterministic** or **stochastic**. Furthermore, they can be dynamic models – which include time as a variable to predict the evolution of system components, or static models - which do not make time dependent predictions (Thornley and France, 2007).

Deterministic models are mathematical models that make definite predictions for various quantities, such as input prices, without assigning probability distributions to those quantities (Thornley and France, 2007). While these models might be suitable in modeling changes in agricultural production systems, deterministic models do not account for risks and uncertainties related to variation in market prices for inputs or outputs, nor do they account for variability in climatic conditions. Both of these uncertainties are highly relevant to agricultural production systems. Modeling the impact of changes to farm economics using a deterministic model can eventually result in an overestimation of the effects of the change on the farm's economics

(Robertson et al., 2012). However, Thornley and France (2007) mention that deterministic models can be a useful first step in performing analyses, and when once developed, these models can be assessed to determine the need for additional stochastic modelling.

Stochastic models are those that account for risk and uncertainty, by incorporating randomness within variables, by assigning probability distributions. These models tend to be more difficult to construct and are harder to test or falsify than their deterministic counterparts (Thornley and France, 2007). Choosing between the two types of models will be determined based on the main objectives of the research, but also by time constraints and a modeler's technical skills.

3.3.1.2 Normative and Positive Approaches to Farm Level Analysis

To evaluate the on-farm implications of changes made to the farming system, Pannell (1996) suggests the use of simulation and/or optimization for analyzing whole-farm implications of a change. In some of these models, **normative approaches** are employed with the purpose of finding optimal solutions for resource allocation (Robertson et al., 2012). Such optimization models involve the specification of behavioral assumptions (i.e., profit maximization) (Weersink et al., 2002). Thus, a normative approach is prescriptive and could be used at the farm level to find solutions to issues based on a set of objectives. In analyzing agricultural systems, the most common optimization analytical method is mathematical programming.

A mathematical programming model is an analytical tool that consists of mathematical relationships together with a set of constraints. The solution provided by this tool is based on the objective specified (i.e., cost minimization) and according to the set of constrains imposed (i.e., limited labor availability). While these analytical tools are useful in providing solutions that best achieve certain objectives (i.e., profit maximization) (Weersink et al., 2002). However, in the absence of such objectives, this technique of analysis is not the right fit.

Positive approaches to farm modeling, such as simulations, are descriptive techniques that include systems of relationships that are created to reflect farm-level activities related to production, finance, among others. (Weersink et al., 2002). This type of modelling contrasts the normative approach simulations, which are used to compare the prescriptive vs. actual behavior of the farm (Robertson et al., 2012).

Whole farm simulations range from very simple to very complex and can be disciplinary, multidisciplinary or interdisciplinary. At one end of the spectrum, there are whole farm or partial farm budget models, also called accounting models or simple simulation models. These relatively simple methods draw on biophysical and socio-economic disciplines and allow for evaluation and comparison of profitability of alternative investments at the farm level (Brown, 1982). These models can be straightforward techniques that support the investigation of the economic subsystem of a farm, which have been overlooked due to their simplicity (Pannell, 1996; Malcolm, 1990).

More complex models, such as integrated dynamic simulation models, that unify various disciplinary models (i.e., bio-economic models that include both the economic and biophysical subsystems of agricultural production systems) have been extremely useful in fostering a better understanding of the behavior of agricultural systems. These complex models allow for a more accurate representation of agricultural systems' complexity, including their dynamic interactions and feedback among its biophysical and socio-economic components. These models are developed with the primary scope of understanding root causes of issues and to understand trajectories of complex and dynamic systems (Darnhofer et al., 2012).

As compared to normative approaches, taking a positive approach to modeling is knowledge intensive, which can make this approach costly and time consuming, especially for models that are more complex. In addition, verification and validation of results has been revealed in the literature as another issue that should be considered (Dent and Anderson, 1971; Strauss, 2005). These issues are addressed in the next subsection.

3.3.1.3 Whole Farm and Partial Farm Level Analysis

In farm management analysis, enterprise budgets are used to evaluate the efficiency of a farm in a given year, or an accounting period to be more precise. In the evaluation process of agricultural projects (at the farm level), budgets provide the basis for evaluation and comparison of the relative profitability between alternative investments (Brown, 1982). A **whole-farm budget** is a tool used to estimate the profitability of an entire farm business, for a major change in the farm's operation (Harper and Kime, 2016). In the case of changes in agricultural systems that trigger significant and long-term effects, a whole-farm budget is strongly preferred over a partial budget (Olson, 2011), since it provides a sounder basis for evaluation of effects (Hoffman, 2010).

Partial budget analyses are considered useful tools in the process of technology adoption, among others. It allows for a comparative analysis, in which one can identify whether a new practice or technology financially outperforms the current one (Alimi and Manyong, 2000; Cornelisse, 2017).

3.3.2 Approach Selection and Justification

Doole and Pannell (2013) concisely explain that the "suitability of a method is determined by its capacity to describe important features of the problem structure, the type of inputs available, the type of outputs required and proposed level of abstraction". In addition, Robertson et al. (2012) mention that in choosing a method, a cost and benefit type of analysis could be of use in distinguishing between techniques.

A whole or partial farm budgeting simulation model is a straightforward technique based on accounting principles, as it allows for the seamless integration of a vast number of biophysical and economic data. This technique supports the evaluation of changes triggered in agricultural production systems and their impact on the profitability of the farm. Whole or partial farm budget simulation methods allow for flexibility and are user friendly. Even though criticized for their simplicity, the technique has a long history and standing in agricultural research and in supporting decision-making. Hoffman (2010) explains that one of the main reasons for which farm budgets continue to be used is because they support a comprehensive understanding of farm-level issues in sufficient interdisciplinary depth.

As previously mentioned in the first chapter of the thesis, one of this study's objectives is to evaluate farm level effects associated with the adoption of proposed beneficial water management practices or technologies. For this goal to be reached one needs an analytical approach, which allows to document systematically changes brought forward by the adoption of new practices. A positive approach to farm level analysis is in line with this objective, and so is a partial budget analysis. Furthermore, since this study is a first attempt at understanding the effect of adopting new practices and technology on tomato, cranberry and dry onion farms, a deterministic model, while simplistic, it is believed to be a suitable approach for this first attempt.

3.3.3 Steps in Conducting a Farm Level Analysis

To perform a farm level analysis to evaluate the impact of managerial changes, several steps are required. Before starting the analysis, it is important to assess the type of information that can be acquired, as this will influence whether a representative farm will be built or if the analysis will rely on case studies. After this step, two scenarios are developed – a baseline and an alternative scenario. Next, the results of the two scenarios are compared. The last stage of the analysis contains the sensitivity analysis, conducted to check the robustness of the results obtained. In the following section, these steps are presented and detailed.

3.3.3.1 Representative Farms or Case Studies

A representative farm model represents a mixture of typical farm characteristics (i.e., size, soil type, crops, crop rotation patterns etc.) pertaining to a specific geographical region. The advantage of using a typical farm model in performing the analysis is threefold: (i) it allows for an understanding of effects of changes on a group of farms located in that region; (ii) it facilitates the aggregation of costs and benefits (Brown, 1982); and (iii) it can provide supporting information for policies (Hoffman, 2010). However, it can only provide some information to individual farm-level decision-makers, because application of results needs to be further tailored to the specifics of the farm of interest (Hoffman, 2010).

In cases where there is not enough information available to construct a representative farm model, case studies of farms can be used as well. The information needed for the analysis of these case studies can be derived through interviews with local producers. Case studies do not allow for generalization of results; however, they can help establish benchmarks that could be useful in developing representative farm models.

3.3.3.2 Developing Baseline Scenarios

A baseline scenario represents an agricultural production system without any changes in method of production, including investments in the new technology or some other type of a project. The baseline scenario model, as opposed to the partial-farm budget model, is a multi-period budget or as explained by Olson (2011), the projected enterprise cash flow budget. The cash inflows and outflows of the farm are projected over a predetermined period (equal to the useful life of the investment / agricultural project). At this stage, future input costs, crop prices and yields need to be determined. There are several approaches in forecasting these parameters.

In deterministic models, it is assumed that important parameters, such as prices and yields, remain constant over the lifetime of the project. Another approach to account for future changes would be to extrapolate these values based on past trends. These two approaches are criticized for not accounting for risks and uncertainties, which are significant in agricultural production systems (Trautman et al., 2012).

A third approach that includes these considerations is a stochastic simulation of these parameters, where probability distribution functions are assigned to each variable. Through simulations, random values are selected for each year. Inclusion of variability and randomness in the modeling of agricultural production systems allows for a more comprehensive analysis, but it can lead to a substantial increase in the complexity of the model (i.e., accounting for variability in crop yields also requires an inclusion of support payments which come into effect in the case of crop losses). Keeping yields and prices constant over the forecasted period on the other hand, might result in an overestimation of the effects of the investment (Brown, 1982).

In summary, there is no solution that can fit all cases, as there are only trade-offs that can be judged in the context of the objectives of the research.

3.3.3.3 Developing Alternative Scenarios

An alternative scenario incorporates the effects of the investment (including change in production technology) on the agricultural production system. The primary step in this stage of analysis is to identify the changes that the new practice/technology would likely bring to the whole farm system and incorporate their direct costs and benefits into the net present value calculations for this scenario. Agricultural producers that have already invested in agricultural projects can represent the main information source. Surveying producers supports the gathering of relevant costs and benefits information at the whole farm level (i.e., initial investment costs, maintenance and operation costs, changes in input levels, output quantity or quality changes, field accessibility changes, soil improvements, etc.).

Even though several changes are likely to be identified by surveying producers, only the effects that indicate direct impact on the farm's profitability are included in the net present value calculations. Data obtained from primary sources need to be adjusted for relevance to the representative farm model through consultation with expert.

3.3.3.4 Comparison of Scenarios

This stage is concerned with the comparison of results from baseline and alternative scenarios. The cash-flow analysis of private producers represents the basis of investment appraisal (Sell, 1991). Several criteria can be used to evaluate investment projects, such as internal rate of return, payback period, and net present value. These indicators measure the profitability (financial desirability) of the investment. While each of these has its advantages as well as limitations, the net present value is the indicator that is generally preferred (Olson, 2011). This is because it incorporates the opportunity costs of having funds committed to the investment and reflects the time value of money (Boehlje and Eidman, 1984).

Present values are calculated by discounting the farm's future cash flows using the market-based opportunity cost of capital -- discount rate (Trautman et al., 2012). Projects are considered profitable if the net present value is above zero, and when comparing two mutually exclusive projects, the one with a higher net present value is preferred (Olson, 2011). In evaluating the profitability of farm-level investments based on this criterion, selection of an appropriate level of the discount rate is important, as it may affect the outcome of the project / investment. There is a wide range of variation in the literature regarding discount rate levels. Investments in agricultural projects carry different levels of risks, depending on the characteristics of the farm and the project. The discount rate is expected to reflect those levels of risk (Trautman, 2012).

3.3.3.5 Sensitivity Analysis

A sensitivity analysis is performed in order to understand the changes in the result or outcome (i.e., profitability of investment) obtained from conducting an economic or financial analysis, when key parameters (i.e., commodity price, yield, etc.) take different values. In case studies, the financial analysis is conducted using data collected from the surveyed producer, or typical values collected from the secondary literature, however, sensitivity analyses are conducted using hypothetical values – a range of values, so that sensitivity to these changes in parameters can be then measured.

3.4 MODELLING ADOPTION DECISIONS

Agricultural producers can influence the impact their farm has on the environment. The outcome depends on the production decisions made by farmers. Farmers are key potential agents of change within a given landscape; however, their capability to change is bounded by the structural elements that surround them. Understanding the components of their decision-making can inform policy makers, which in return, could help devise efficient policy instruments to reach a common social goal. Modelling farmers' behavior allows one to understand the factors that contribute to or hinder the adoption of innovations.

The literature indicates that the configuration, under which factors come together to explain adoption, depends primarily on the biophysical conditions and the location of the production systems above all. This explains the large number of studies on the adoption behavior of agricultural producers, and the variation in the configuration of these factors for an individual locale -- socio-economic and environmental setting. The decision-making universe of the agricultural producers is bound to have a vast number of factors that interplay; however, if the modeling of the behavior is done with a policy response in mind, a more useful model is one that can allow for a policy intervention, if required.

There are several theories that have been commonly used for understanding and modelling farmers' behavior related to adoption of new practices and technologies. The most commonly used one is the Theory of Diffusion, put forward by Rogers in the early 1960s (Rogers, 2003). Another theory of interest has been the Theory of Planned Behavior, proposed by Fishbein and Ajzen (1977). In the following section, these theoretical frameworks will be discussed in detail, after which determinants of adoption, reasons for adoption and barriers to adoption are described.

3.4.1 Theory of Diffusion of Innovation

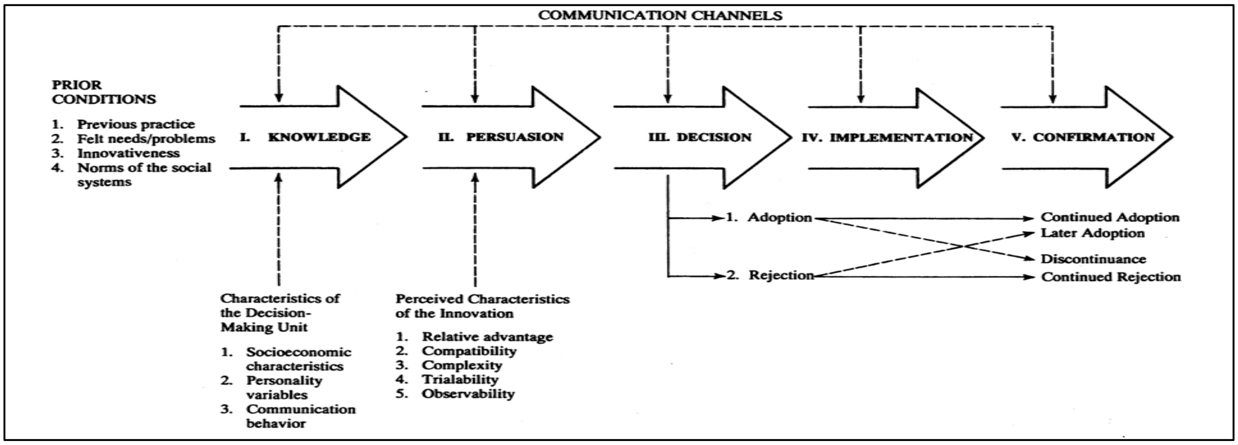
The Theory of Diffusion of Innovation developed by Everett Rogers in 1962 (Rogers, 2003), is one of the most comprehensive and most commonly used theoretical frameworks for studying the adoption of agricultural innovations. Although this theory was developed in the field of Rural Sociology, it has been influenced by a variety of other fields and has a long-standing tradition in agricultural economics in explaining farmers' decisions regarding the adoption of innovations.

According to this Theory, the decision-making process is framed as "an information-seeking and information-processing activity, where an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation" (Rogers, 2003). This process includes multiple stages: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation (Rogers, 2003). In the first stage, the individual becomes aware that the innovation exists. In the second stage, the individual pursues the new knowledge gained, by acquiring information regarding the innovation of interest. This is also the stage at which attitude formation takes place -- the individual can form a positive or negative attitude towards the innovation. Following these two stages, the framework proposes that individuals make a decision regarding the adoption or rejection of the innovation, after an evaluation of alternative options. This is the stage during which a choice is made. In the implementation stage, the individual tests the innovation, through trials or uses it on a small scale, where the impacts are minimal. The last stage, also known as the confirmation stage, is when a decision is reached to either pursue the innovation further and adopt it a at a larger scale, or the decision to cease its use can be reached in this final stage (Rogers, 2003; Duff et al., 1992; Kulshreshtha and Brown, 1994).

Under this systematic framework, the rate of adoption of technologies is influenced by several factors, which are grouped into three main categories: (1) prior existing conditions, (2) characteristics of the innovator, and (3) characteristic of the innovation. In Figure 3.1, it can be noted that Rogers (2003) denotes some prior conditions, which affect the innovation-decision process. These conditions are (1) previous practice –- either a practice used by the innovator or a prevalent method of doing things within the group of peers, (2) felt needs or problems –- impetus for change coming in the form of necessity of addressing issues, (3) innovativeness –- characteristic of the innovator, and (4) norms of the social systems – given that individual decisions are embedded in social systems, the prevalent behavioral pattern within this system will influence the individual’s choice. Individuals are more likely to adopt an innovation that conforms to societal norms.

Another important group of factors, relevant to the innovation adoption decision process, is characteristics of innovations, as perceived by the innovator. Rogers (2003) divides innovations characteristics into five categories:

1. **Relative advantage** is “… the degree to which an innovation is perceived as being better than the idea it supersedes” (Rogers, 2003). The implication being that the likelihood of adoption increases, as the innovation is being perceived as a better alternative. The relative advantage of an innovation has been conceptualized in previous studies as a financial indicator, influenced by innovators’ characteristics. However, there have been studies that used a broader definition, which included non-financial considerations as part of the relative advantages an innovator receives from adoption (Reimer et. al., 2012).



Source: Rogers (2003)

Figure 3.1. Roger's Diffusion of Innovations Five Stage Model

2. **Compatibility** is "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, 2003). In this sense, compatibility goes beyond referring to a technical fit within an already existing agricultural system, but it refers to a broader fit, within the producers' individual norms, and, by extension, an alignment with social norms as well.
3. **Complexity** of an innovation represents "the degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers, 2003). A high degree of technical complexity of an innovation can potentially hinder its rate of adoption. An innovation perceived as technically complex signals to the innovator that time needs to be allocated to learn, which may deter its adoption.
4. **Trialability** is "the degree to which an innovation may be experimented with on a limited basis" (Rogers, 2003). In the context of agricultural systems, a technology with increased modularity has the potential to reduce risks of adoption, because it can be easily trialed on a smaller scale at which effects are also easier to manage. A trialable innovation allows the innovator to interact directly with it, and to understand its relative advantage, compatibility, complexity and observability. This in turn reduces the risk associated with the adoption of this innovation (Pannell et al., 2006).

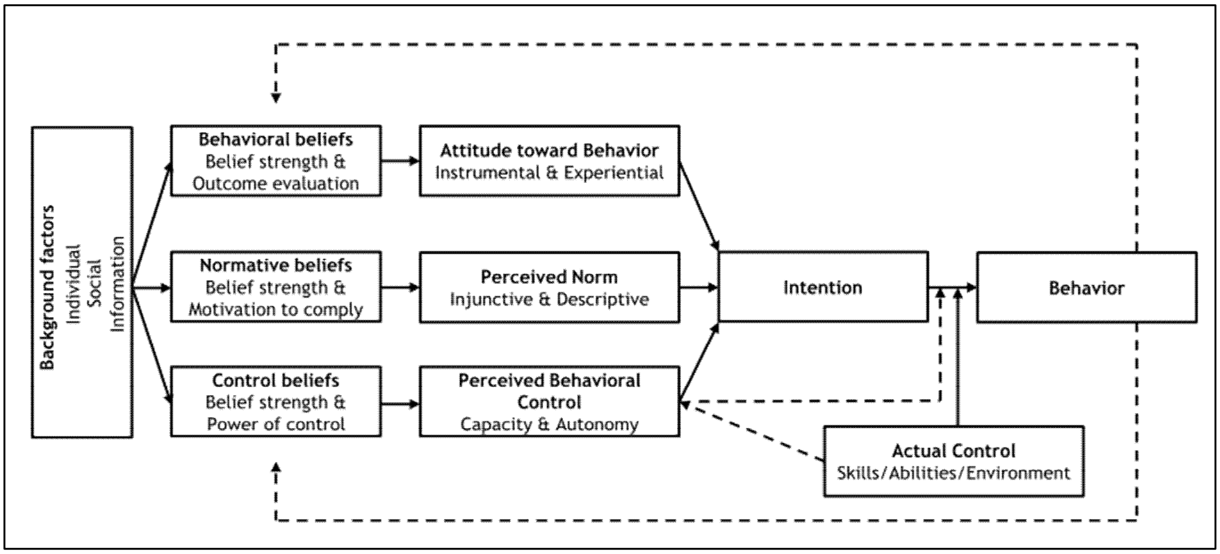
5. **Observability** refers to “the degree to which the results of an innovation are visible to others” (Rogers, 2003). Individuals are more likely to adopt an innovation if benefits can be observed.

This multistage decision process, as conceptualized by Rogers (2003), can be perceived as a continuum, with overlapping stages rather than discrete steps. Under this conceptualization, the adoption is a learning process, in which communication is an important factor. In addition to the factors mentioned above, another important group of factors in the decision process of adoption relates to individuals’ characteristics. Rogers (2003) further breaks these characteristics into: (1) socio-economic characteristics, (2) personality variables and (3) communication behavior. These factors will be further discussed in more details in Section 3.4.4.

Rogers’ Diffusion of Innovations Theory provides a comprehensive understanding of the components (whether they are endogenous or exogenous to the individual) involved in a decision-making process. However, the theory was developed with the intentions of establishing the conditions for, and means by which, innovation spreads most readily. It focuses on communication as a means of influencing perception. The theory provides little insight into the actual decision-making process of an individual. One can understand from the theory the building blocks of that decision, but not necessarily know how they come together in a cohesive manner to understand individual decision-making. Given that this study’s focus is to understand the factors that influence an individual’s choice related to adoption of an innovation, another theoretical framework that allows us to logically organize the factors, which Rogers (2003) has identified in his work, is reviewed.

3.4.2 Reasoned Action Approach

The Reasoned Action Approach represents an extension of the Theory of Planned Behavior, which in turn was an expansion of the Theory of Reasoned Action. These theoretical models assume that attitudes are good predictors of behavior. It originated in the field of social psychology. Its impetus was to put forward an understanding of attitudes and how these connect to the behavior that is pursued. Broadly interpreted, the Reasoned Action Approach suggests that an individual is more likely to engage in a behavior if the attitude towards that behavior is positive, and if peers, friends or family members support and engage in that behavior. In addition to these factors, the extent to which a person feels capable of engaging in that behavior is also likely to influence the outcome. The constructs of this theory are presented in Figure 3.2, based on the work by Fishbein and Ajzen (2011).



Source: Fishbein and Ajzen (2011)

Figure 3.2. Reasoned Action Approach

The Theory of Planned Behavior was developed with the intent to understand and predict behavior. It represents the work of two researchers, Martin Fishbein, a communications scholar, and Icek Ajzen, a scholar in the field of psychology. Their collaboration started in the 1960s and their goal was to develop a parsimonious model, which explains human social behavior (Gold, 2011). Their seminal work, the Theory of Reasoned Action (Ajzen and Fishbein, 1980; Fishbein and Ajzen, 1977), posits that an individual's behavioral intention represents one of the better predictors of the individual's behavior. This theory explains that behavioral intentions are determined by two factors: attitude towards behavior, and social norms. Ajzen (1985) expanded the Theory of Reasoned Action into what is known as the Theory of Planned Behavior, by adding a third factor which influences behavioral intentions – perceived behavioral control (Madden et al., 1992). In recent years, these two theories have been unified under the Reasoned Action Approach, which extended the theoretical model to include actual control as a determinant of behavioral intentions and behavior (Fishbein and Ajzen, 2011). The key concepts of this approach are described in detail below.

1. **Attitude towards behavior** refers to whether the individual sees the behavior as favorable or not. Under this framework, attitude is categorized into instrumental (i.e., rewards) and affective attitude (i.e., feelings), which in turn is explained by a belief about the outcome of the behavior and an evaluation of that expected outcome. For example, let us assume that a farmer's attitude towards the adoption of subsurface drip irrigation is "adoption of this practice represents a better alternative than the current irrigation system". This represents the farmer's attitude towards adoption. One possible pathway, by which this attitude was formed, might have had to do with the farmer holding the belief that "subsurface drip irrigation increases crop yields" and the evaluation of that belief "increasing crop yields would help my bottom line". Fishbein and Ajzen (2011) caution that having these alignments in attitude can lead to the formation of a positive behavioral intention; however, while this condition is necessary in voluntary decision-making, it is not necessarily sufficient for the enactment of that behavior. This is especially the case when the attitudes are in relation to a general concept related to that behavior. In the above example of the agricultural producer, an equivalent of that would be that if the farmer had a positive attitude towards water conservation that would make the farmer more likely to adopt a water conservation technology for their agricultural production system. Two important distinctions need to be made in relation to this theory: (1) That attitude alone is a poor predictor of behavioral intentions and by extension, a poor predictor of behavior itself. (2) Attitude towards specific behaviors are better predictors of that behavior than of general attitudes.

2. **Subjective norms** represent the second factor determining behavioral intentions. They refer to the beliefs an individual holds in relation to others' perception of the behavior – others whose opinions are important to the individual (i.e., family, friends, peers, etc.). Subjective norms are related to social norms and the position an individual takes in relation to those standards. Subjective norms are grouped into two normative beliefs. The first one is the individual's perspective on others' beliefs related to the behavior, and the second one is the individual's motivation to comply or conform to that social norm (Fishbein and Ajzen, 2011). Let us use the farmer's example again. Let us assume that the farmer's subjective

norm is “adopting a subsurface drip irrigation technology on my farm is the appropriate thing to do”. One potential pathway of acquiring that belief could have evolved from “my neighbor, who is a more experienced farmer and thinks this is a good idea” and “his opinion is valuable to me, so I think I should listen to him”.

3. **Perceived Behavioral Control** refers to an individual’s perceived ability to follow through on the target behavior. An individual’s perception of how easy it is to perform behavior is referred to as a control belief, which represents the determinant of perceived control. This component was added to the theory in order to make the framework more general, in that it included situations where the power of choosing a certain behavior did not necessarily reside within the individual (Ajzen, 1985). In a comparison of the two theories, researchers found that perceived behavioral control improves intention and behavior prediction. This effect of the perceived behavioral control was seen in situations where “there was not complete volitional control” over the behavior (Madden et al., 1992). Conversely, in situations where individuals perceived that they had high levels of control regarding target behavior, there was no significant relationship found between perceived control and behavior (Madden et al., 1992). Using the farmer’s adoption of the subsurface irrigation system example, let us assume that the farmer has low perceived behavioral control “I cannot use this irrigation system on my farm”, which in turn can stem from control beliefs like “I do not have the necessary money and time to adopt this technology”.

4. **Actual Control** was the last component added to the model, which represents the individual’s actual capacity to enact the behavior. Actual capacity in this sense refers to the skills, abilities and environmental factors (Fishbein and Ajzen, 2011).

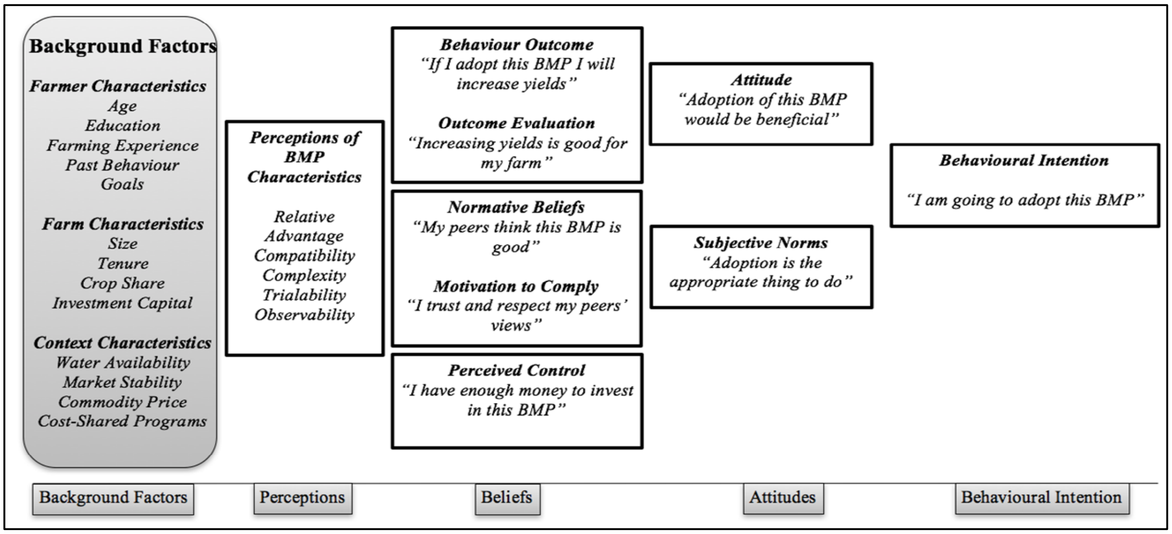
In summary, the Reasoned Action Approach assumes intentions are strong estimators of behavior; and in turn, they are determined by attitudes people hold regarding a given behavior of interest, other’s views of it, and the degree to which they feel capable of enacting that behavior. The theory does not directly link characteristics of individuals with behavior; however, it does mention the pathway, as Ajzen (2011) explains it as follows:

> *"The theory does not specify where these beliefs originated; it merely points to a host of possible background factors that may influence the beliefs people hold – factors of a personal nature such as personality and broad life values; demographic variables such as education, age, gender and income; and exposure to media and other sources of information. Factors of this kind are expected to influence intentions and behavior indirectly by their effects on the theory's more proximal determinants."* (Ajzen, 2011)

This theoretical framework was used by multiple scholars in their research intended to predict or understand factors affecting farmers' adoption decision-making (Lynne et al., 1995; Lynne et al., 1988; Carr, 1988; Reimer et al., 2012). Lynne and colleagues evaluated the determinants of water conservation technology adoption, among strawberry growers in Florida. Their results show that the Theory of Planned Behavior provides a robust framework for understanding behavior, given situations where there are constraints on volition. The researcher argues that both perceived and actual control should be evaluated when trying to understand adoption behavior (Lynne et al., 1995). Carr (1988) looked at farmers' attitudes in relation to preservation of shelterbelts on their farms. The researcher found that farmers' positive general attitude towards protecting wildlife, was a poor predictor of decisions farmers made on their farms, which included the removal of the shelterbelts for economic reasons (Carr, 1988; Beedell and Rehman, 2000). Reimer and colleagues studied the perceptions of farmers in Indiana, in relation to the adoption of several beneficial management practices. Their research showed that there is a link between farmers' perception of the beneficial management practice and the likelihood of those practices being adopted (Reimer et al., 2012).

3.4.3 Joint Approach, the Reasoned Action Approach, and Diffusion Theory

Linking Diffusion Theory with the Reasoned Action Approach has several benefits. First, it provides a comprehensive understanding of an individual's decision-making in terms of both determinants and processes. Diffusion Theory shows how background factors like an individual's characteristics influence the process, together with the role played by an individual's perception of the innovation. On the other hand, the Reasoned Action Approach does not focus on the background factors, which are assumed to affect the decision-making process indirectly. However, this theory focuses on the process involved in the decision-making – formation of beliefs, attitudes, behavioral intentions and behavior. The joint theoretical framework is shown in Figure 3.3.



Source: Adapted from Reimer et al. (2012); Fishbein and Ajzen (2011); Rogers (2003)
Figure 3.3. Finding Common Ground: Diffusion of Innovations and Reasoned Action Approach

Secondly, the joint framework positions factors affecting behavior in the order of their power to predict behavior. Behavioral intentions represent the closest proxy to the actual behavior, whereas background factors like age, education, experience, and farm size, are considered the farthest proxies of behavior prediction. Related to this concept of proximal predictors of behavior, it is important to not disregard the more distant estimators, as it has been shown that they can be good predictors of behavior. In addition, they are easier to collect and evaluate. However, the fact, that background factors are more distant predictors of behavior, could explain the reason behind inconsistent results obtained from using background factors in determining behavior, especially in the area of agricultural producers' adoption decision-making. Several meta-analyses and literature reviews, that have looked at identifying background factors as determinants of adoption, have shown that there is a large variation in the background factors that predict adoption (Pannell et al., 2006; Knowler and Bradshaw, 2007; Prokopy et al., 2008; Baumgart-Getz et al., 2012). Given that these background factors determine an individual's behavior indirectly, the configuration in which they come together to influence an agricultural producer's adoption decision regarding a specific BMP, will vary across individuals, farms, innovations, and the context in which an individual operates.

Lastly, the joint framework as presented in the Figure 3.3 and initially proposed by Reimer et al. (2012), pins the position of perceptions of the practice or technology in the decision-making process. Rogers (2003) was the first one to explain the importance of these factors in the adoption process. Previous studies have incorporated these factors and found them to be important determinants of adoption. When looking at various conservation practices in the USA, Reimer et al. (2012) found several perceptions of the practices to influence adoption; however, seeing the BMP as having relative advantage – being better than the technology or practice it supersedes, was an important factor in adoption across all practices.

In this study, the focus is on understanding the configuration of background factors and their importance in the adoption process of improved irrigation technologies and practices for three crops. Furthermore, another objective of this research is to understand the role played by perceptions of BMPs in making adoption decisions, especially when used together with these background factors. In addition, there is also interest in understanding what factors contribute to seeing a BMP as a better alternative than the one it supersedes. In the following section, determinants of adoption are described based on a review of previous studies.

3.4.4 Determinants of Adoption

The adoption of new agricultural practices or technologies represents a complex process, influenced by a multitude of factors, which eventually determine the outcome of a given innovation process, as acknowledged by Kulshreshtha & Brown (1993) and Stonehouse (1996). Viewed from a broad perspective, the adoption process of agricultural innovations is influenced by an array of personal characteristics of the decision maker, by the specifics of the innovation, as well as by social, economic, cultural, and institutional factors (Stonehouse, 1996; Pannell et al., 2006). The studies selected for this review represent a large variety of agricultural practices and technologies and lump together experiences from several distinct countries: Canada, United States of America, Australia and others. These studies have suggested factors that could be divided into 4 categories: (1) Farmer characteristics and attitudes, (2) Farm characteristics, (3) BMP characteristics, and (4) Context characteristics, as shown in Figure 3.4.

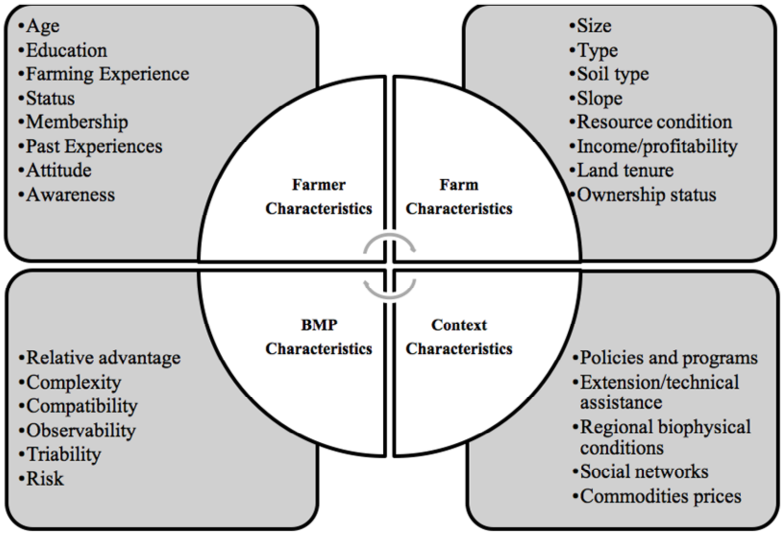


Figure 3.4. Determinants of Adoption by Category

3.4.4.1 Farmer Personal Characteristics and Attitudes

In the process of deciding whether to adopt agricultural innovations, farmers form perceptions, attitudes, and behavioral intentions, through the filters provided by their own personality, age, education, farming experience, position within their social advice organizations or information networks, and of course their past behavior. These are all considered background factors in the decision-making process, and are assumed to indirectly influence the adoption or rejection of a practice. Furthermore, several studies have also included farmers' overall attitudes [2]and environmental awareness as proxies to behavior prediction, as part of the background factors. An overview of these studies can be found in two review articles on the issue of adoption of beneficial management practices (Prokopy et al., 2008; Baumgart-Getz et al., 2012). In the following section, some of these common factors are discussed.

Some of the most common factors used to predict adoption of agricultural innovations are the personal characteristics of the individual involved in the adoption process. The age of the

[2] Fishbein and Azjen (2011) highlight the importance of measuring behavior-specific attitudes, since it has been shown that general attitudes are not good predictors of intentions. In addition, Baumgart-Getz et al. (2012) also emphasize that: "… there should be a clear link between these variables and BMP adoption. Too often attitudinal and awareness indicators have been included in studies without defining a clear connection to BMP adoption…attitudinal questions must be behavior-specific rather than universal attitudes".

farmer and the years of farming experience are frequently used to explain adoption in previous studies. However, results are mixed, indicating that these factors can influence adoption either positively or negatively (Traoré et al., 1998; Lamba et al., 2009). Related to the age of the producer, Baumgart-Getz et al. (2012) explain that older farmers are less likely to adopt BMPs because of their shorter planning horizon. Other studies have pointed out that age, as a determinant of adoption, can become relevant in cases where there are large lags between time of investment and payoff (Pannell et al., 2006). Regarding a producer's farming experience, Kulshreshtha and Brown (1994) explain that the years of experience can determine a farmer to be more willing to try new practices. Conversely, however, routine can set in, as the farmer gets older.

A higher education level attained by agricultural producers has been found by some studies to be a positive factor in implementing new BMPs (Ghazalian et al., 2009; Serman, 1999). The premise behind these results is that education supports a better understanding and dissemination of available knowledge regarding new practices or technologies, speeding up the adoption process (Kulshreshtha and Brown, 1994). As highlighted by Prokopy et al. (2008) and Baumgart-Getz et al. (2012), some researchers have found that higher education was positively correlated with adoption and it was a statistically significant predictor. However, in other studies, education was not found to be statistically significant (Prokopy et al., 2008; Baumgart-Getz et al., 2012).

An individual's status within their social network or community has also been revealed a factor influencing adoption of innovations. Social networks can be portrayed as structures through which information flows. In the context of BMP adoption, the flows can be information or advice about the practice. Studies have found that access to information, the quality of the information, and farmers' connectivity to local agricultural groups, are some of the important factors pertaining to adoption (Baumgart-Getz et al., 2012). Kulshreshtha and Brown (1994) have explained that a farmer's higher social status can be positively correlated with adoption due to a better contact with extension services. This, in turn, can diminish the risk associated with adoption as enough information has been acquired. However, a higher social status could also have the opposite effect on adoption. The higher an agricultural producer's status within a network, the more constrained they are likely to feel in their decision-making, if the practice is not considered socially acceptable.

An Alberta study (Baird et al., 2016) looked at farmers' advice networks pertaining to land-management decisions. Agricultural producers were found to rely on regional advisors for advice, making them the most influential agents in the adoption process. Interestingly, and in contrast to other findings, this research also showed that local agents, like family, neighbors and peers play a smaller part in the advice network, and subsequently in the adoption decision itself (Baird et al., 2016).

With limited time available to them, farmers' make use of social networks and reduce the amount of time needed to pursue information regarding a practice or technology. Pannell et al. (2006) noted that a typical farmer might embark on 30 new learning projects within a one-year period, which may lead to limited time availability.

Besides socio-demographic characteristics, another set of factors affecting adoption relate to farmers' general attitudes towards conservation and their environmental awareness (Prokopy et al., 2008). Awareness of environmental problems located either on-farm or off-farm, can be an antecedent to attitude formation regarding a specific BMP, and can indirectly influence the adoption of a BMP. If the BMP is thought to have the capacity to tackle the environmental problems, a positive attitude could be formed, which can lead to the adoption of the proposed BMP. However, Knowler and Bradshaw (2007), Prokopy et al. (2008) and Baumgart-Getz et al. (2012) have found that predominately these constructs were inconsistently defined, and in a majority of cases were neither specific to the BMP of interest, nor significant predictors of adoption. In some cases, farmers involved in conservation or environmental organizations were also found more likely to adopt new BMPs. (Ghazalian et al., 2009; Lamba et al., 2009).

Farmer's attitude towards risk is another determinant of adoption that has frequently reported. A risk-averse farmer is thought to be more likely to adopt an innovation as long as it is perceived to reduce risk. Conversely, he/she would reject the adoption of an innovation perceived to increase risk (Pannell et al., 2006). This type of farmer could also be more comfortable with a delayed adoption of BMPs, allowing for these practices to first mature; while a risk-taker could, in theory, be more likely to adopt a BMP earlier, if there are no other constraints. However, a literature review by Prokopy et al. (2008) has shown that in most cases a farmer's attitude towards risk does not contribute to explaining adoption decisions.

3.4.4.2 Farm Characteristics

In addition to characteristics inherent to the decision-making unit or individual, most studies focusing on the adoption of agricultural practices or technologies have included farm related characteristics affecting it (Knowler and Bradshaw, 2007; Baumgart-Getz et al., 2012; Feder and Umali, 1993). These farm related characteristics are typically grouped into two categories (i) farm biophysical characteristics and (ii) farm financial and managerial characteristics.

Farm size or crop size have been considered to have an influence on the adoption of BMPs. Related to the farm size, the common assumption is that the larger the farm, more likely it is for adoption to take place. Initial investments are needed in order to adopt a new practice; therefore spreading those costs over a larger area provides an explanation for the relationship rationale. However, empirical results from the literature indicate mixed effects of the farm size on the adoption process (Baumgart-Getz et al., 2012). This is not surprising since this variable can act as a proxy for a variety of other socio-economic factors. Furthermore, the effect of this variable might depend on the BMPs being considered.

In relation to the crop size, the assumption behind the relationship of this variable with adoption of a BMP comes from the capacity of crop size to be a proxy for the degree of specialization of a farmer. Hence, for a farmer with a large percentage of revenue coming from a certain crop, and a BMP intended for the crop of interest, the farmer might have added incentive to adopt it, if the BMP is perceived as a good option for the farm.

Several other biophysical characteristics have also been found to influence the adoption process, such as soil type and slope, water availability, presence of natural resource problems and others (Knowler and Bradshaw, 2007). The degree to which these variables influence the adoption process depends highly on the specifics of the BMPs to be adopted.

There are several variables reflecting farm financial and managerial characteristics; however, within the context of BMP adoption, some have been more commonly investigated. These factors include farm income or profitability, land tenure, ownership status, income source (on and off-farm), farm type, etc. (Prokopy et al., 2008; Feder & Umali, 1993). Lack of financial viability is expected to restrain adoption of innovations by reducing the farmer's capacity to adopt (Pannell et al., 2006). For the most part, the literature provides support for this claim (Knowler & Bradshaw, 2007). Regarding land tenure, it is hypothesized that farmers owning farmland are more likely to adopt BMPs, as they are believed to better maintain the farm's natural assets (Knowler and Bradshaw, 2007), in addition to reaping the benefits over the entire life of the said investment. Capital (defined as investment on farm), was found to be the best financial predictor of adoption, based on a literature review provided by Baumgart-Getz et al. (2012).

Farm related variables, like farmer related factors, have been found to influence adoption to various degrees. Furthermore, there is no precise configuration of factors that can be prescribed to be associated with the adoption of BMPs. Furthermore, these factors appear to be context dependent and BMP specific. While indirect determinants of adoption behavior, these indicators are easy to collect and have been shown to have good predictive power. The only caveat is that it is unlikely to be able to use a predefined set of farm or farmer related variables to determine behavior surrounding the adoption of agricultural practices. Given that adoption decisions are influenced by the characteristics of innovations, understanding these factors related to the BMP can influence adoption decisions is described next.

3.4.4.3 Beneficial Management Practice Characteristics

While most studies that have focused on the adoption of agricultural practices and technologies have highlighted individuals' characteristics and the characteristics of the farms, along with other socio-economic variables influencing the adoption process, a limited number of scholars have also suggested characteristics of innovations as determinants of adoption (Reimer et al., 2012; Wejnert, 2002). These BMPs characteristics are as perceived by farmers. Furthermore, while some studies have taken the approach of treating the different perceived characteristics of the BMPs as belonging to Rogers original five groups (relative advantage, compatibility, complexity, trialability, and observability), others have argued that these categories can be collapsed (Pannell et al., 2006).

The relative advantage of the BMP being adopted, over the one that it supersedes, represents one of the most significant factors influencing this process (Pannell et al., 2006; Reimer et al., 2012). The relative advantage refers to the net benefits or costs brought on by the new BMP. These benefits or costs can be either financial or non-financial in nature – environmental, social, and cultural advantages, etc. However, past studies have revealed that BMPs with net financial benefits were more likely to be adopted, even though some exceptions were encountered (Reimer et al., 2012).

Compatibility of a BMP with the agricultural system in which it is introduced, complexity of the BMP, possibility of testing the new BMP as well as the risk it poses, are other characteristics that directly impact its competitive advantage, and implicitly the adoption process (Reimer et al., 2012). There are multiple other factors that influence the actual and perceived relative advantage of a new BMP, such as: farm and farmer characteristics, governmental policies, establishment costs, and time between implementation and results (Pannell et al., 2006).

In the final analysis, the evaluation of these different costs and benefits is ultimately an assessment pertaining to the farmer. For this reason, it is highly important to understand the interconnection between the factors affecting the adoption of BMPs. Pannell et al. (2006) explains that farmers, with primary goals and motivations oriented towards profitability, are unlikely to adopt practices or technologies that have a negative effect on the farm profitability. Non-profitable BMPs are more likely to be adopted by farmers with stronger environmental protection convictions. However, under these circumstances, evidence from past research suggests that the scale of adoption is limited and that generally the cost of adoption in these cases is relatively small in comparison to the scale of the farm's financial situation.

3.4.4.4 Context Characteristics

Agricultural systems are embedded in larger ecological, social, economic and political systems, meaning that the adoption process is also influenced by a variety of factors beyond the farm level. Some of these factors and their importance in the process are presented in this section.

Overarching agricultural policies, together with programs oriented towards tackling environmental problems associated with agricultural production systems, affect the adoption of BMPs, either by providing incentives (i.e., cost-share programs) or conversely disincentives. Furthermore, other institutional factors that are often positively correlated with adoption of BMPs are technical assistance and extension services (Stonehouse, 1996). Knowledge diffusion represents one of the critical factors in the adoption and diffusion of any type of innovation. This function is formally performed by extension agents, but social networks, local rural communities, peers, etc. can also be sources and channels of communication, influencing knowledge diffusion, and thereby the adoption process.

Regional environmental conditions can also influence the adoption process. For example, in cases where water quantities are dwindling and agricultural producers depend highly upon the water resources, adoption of technologies or practices that make use of resources in a more efficient manner could be considered as part of the solution. In other cases, research has shown that water supply reliability issues acted as a deterrent to adoption (Marques et al., 2005).

Several studies looked at the effect of commodity prices on the adoption of improved practices and technologies. In some cases, an increase in output prices can make a practice sufficiently attractive for an agricultural producer, thus positively affecting its adoption. Evidence from the literature provides mixed results, as with the case of input prices (Shiferaw et al., 2009).

In the following section of this chapter, exploring determinants of adoption, as they pertain to the adoption of agricultural innovations, is pursued, particularly for the Canadian experience.

3.4.5 Determinants and Reasons for Adoption: A Canadian Perspective

As previously stated, determinants of adoption vary across regions and across innovations. Given this finding, it is important to review the Canadian literature on this topic. There are several authors that have covered agricultural innovation adoption, focusing on different provinces and practices.

An earlier study looked at identifying the type of conservation practices used by farmers in Ontario for soil and water protection. Conducted by Smithers and Smith (1989), this study examined barriers and drivers to the adoption of the conservation practices and represented the socio-economic component of a governmental program entitled Soil and Water Environmental Program. Several variables were reported in this study to influence the adoption of conservation practices among Southwestern Ontario agricultural producers: farm size, annual sales, awareness of on-farm environmental issues, membership in farm organizations, and farmers' age. In terms of land tenure, these authors' findings show that landowners are more likely to invest in beneficial practices, while renters are less likely to do so.

Also, part of the same governmental soil and water conservation program, led by Ontario in collaboration with the federal government, Serman (1999) surveyed 427 farmers in order to understand which factors influenced their adoption of soil and water conservation practices. The findings of this study indicated that several farm and farmer related variables were positively correlated with the adoption of these conservation practices. Farmers with higher levels of education had higher adoption rates, in addition to age and farming experience. Other variables positively associated with adoption were gross annual sales, farm size, and the number of crops cultivated.

Also focused on Ontario' farmers, Lamba et al. (2009) interviewed 164 farmers in order to understand the factors affecting adoption of various BMPs, of which the most commonly implemented ones, were the use of forage in crop rotations, conservation tillage, and improvements of manure storage or handling. This study found that BMPs are more likely to be adopted by younger farmers, which have achieved a higher education and are members of farm-related environmental programs. This research also found that farm characteristics, such as gross sales and farm size, are important determinants when it comes to adoption of agriculturally sound practices. Filson et al. (2009), who surveyed 481 farmers, located in five distinct watersheds in Southern Ontario, obtained similar results. Farms with larger acreage and high revenue shares were associated with an increased rate of adoption. Farmer related characteristics, like age and education, were not found to influence adoption.

Also pertaining to BMP adoption, in a study by Smithers & Furman (2003), the underlying reasons associated with the engagement of Ontario farmers in environmental farm planning programs were investigated. Results suggest that individual characteristics of farmers were major determinants in the decision to participate in such programs. Characteristics that were major determinants of participation in such programs included farmer's intrinsic motivations regarding the environment, their past experiences, their perception of the environmental program, as well as physical characteristics of the farm, like on-farm environmental conditions.

Bjornlund et al. (2009) investigated factors affecting adoption of improved irrigation technologies and management practices in the province of Alberta. Farmers surveyed for this study revealed that even though several reasons were important in making the decision to implement changes, improved crop yield or quality, constituted the most important motivation. Reduced energy cost, water use and labor were other relevant motivators for adoption, whereas reduced fertilizer use, pesticide loss or soil erosion reduction were not as important in their decisions. Exhaustive implementation of all practical water-saving techniques, poor commodity prices, sufficient water supply, and financial constraints were some of the reasons for non-adoption of improved water practices or technologies in Alberta (Bjornlund et al., 2009).

Manning (1988) studied the factors affecting irrigation adoption among Saskatchewan farmers. Results of the survey show that some of the most important reasons to adopt irrigation technology included yields increases, profitability, reducing the effects of drought, and ensuring water availability. Non-adopters reported that the cost of the technology, low crop prices, salinity concerns, and capital availability were their primary constraints.

Smithers and Smith (1989) also found that farmers are motivated by several factors in their decision to adopt soil and water conservation practices. One of the most frequent responses given by the farmers they interviewed, was because of long-term productivity concerns, seconded by the need to address an environmental problem and also because it lowers production costs. Technology inadequacy, lack of need, and slow returns on investment were some of the barriers that Ontario farmers encountered.

3.4.6 Conditions of BMP Adoption

This section explores conditions under which farmers are more likely to adopt new BMPs. Given that adoption of a new practice or technology at the farm level is a complex process influenced by a multitude of factors, one can assume that conditions fostering the adoption of these agricultural innovations will also be complex. An alignment of multiple conditions might be needed for BMPs to be implemented. Four such conditions are described below.

3.4.6.1 Degradation and limited availability of natural resources

Agricultural production systems depend on the health and function of the ecosystems in which they are embedded. The productivity and financial viability of agricultural systems can be negatively impacted by degraded natural resources or by their lack of availability. Under such conditions, and if the land manager is aware of the problem, he/she is likely to explore alternative practices or technologies that can improve the condition of these natural resources. Poor resource conditions that have no effect on the farm's productivity, but for which the farmer is responsible (i.e., GHG emissions), could also contribute to the farmer's adoption of a new BMP. This could be due to intrinsic motivations, social pressure, or institutional pressures (i.e., governmental regulations). Shiferaw et al. (2009) discussed resource scarcity as a stimulus to the adoption of innovations.

In the Canadian context, Smithers and Smith (1989) examined barriers to the adoption of conservation practices encountered by Southwestern Ontario farmers. In this study, farmers were requested to comment on the conditions under which they would adopt new conservation practices.

3.4.6.2 BMP compatibility and relative advantage

Besides the necessity of the new BMP, its applicability within the agricultural system is assumed to represent another condition. The greater the BMP compatibility with existing machinery, agronomic practices, and crop rotations, the lower the transaction costs and greater the benefits (Pannell et al., 2012). The effectiveness of the BMP relates to its successes in enhancing the conditions of natural capital and/or increasing the flow of services it provides. Existing proof of BMP effectiveness represents an important condition under which a farmer would adopt a BMP. It is important to distinguish that there might be a discrepancy between the actual and perceived effectiveness of an innovation. Farmers generally acquire proof of effectiveness through social networks, governmental extension agents or trial and error. This matter is closely linked to the issue of observability of the results accruing from adoption of innovations. Reimer et al. (2012) and Pannell et al. (2006) note that observability of results from a new practice or technology do condition BMP adoption. Farmers interviewed by Smithers and Smit (1989) reported that efficiency and cost-effectiveness of a BMP are the most important conditions for adoption.

Farmers adopt new practices and technologies based on the relative advantages that these alternatives are expected to provide. The general rule is that a BMP is adopted if it is perceived to provide net benefits. The benefits can be higher net returns, lower financial risks, improved environmental conditions, etc. It is important to recognize that valuation of benefits depends on the farmer's own set of goals and motivations. While a farmer with strong environmental protection convictions is more likely to place heavier emphasis on positive environmental effects, while a profit-oriented farmer is more likely to value higher financial effects. Greiner et al. (2009) studied the links between farmers' motivations and their influence on the type of BMPs being adopted. Firstly, their results indicate that there is a connection between motivations, farmers' attitudes toward risk, and the adoption of BMPs. Farmers with conservation in mind, develop intrinsic motivations for the adoption of conservation practices, while economically or financially motivated farmers refrain from adoption, unless incentives are provided (Greiner et al., 2009). Reimer et al. (2012) has noted that even though other types of benefits are relevant for adoption, financial benefits provided by the practice are suggested to be the most important. Therefore, farmers usually adopt BMPs that are perceived as profitable, and reject BMPs that carry net financial costs. Results from surveys of farmers residing in Southern Ontario also indicate that farmers are willing to adopt BMPs only if they are financially feasible (Lamba et al., 2009). Short time lags between investment and payoff, and low implementation costs are also conditions under which farmers are likely to adopt new BMPs (Pannell et al., 2006).

3.4.6.3 Financial and extension assistance availability

Smithers and Smith (1989) and Greiner et al. (2009) have identified the availability of financial incentives (i.e., grants, cost-share programs, tax benefits, etc.) as an important condition under which new practices are more likely to be implemented. Lamba et al. (2009) also emphasized that farmers in Southern Ontario prefer less governmental involvement and more technical, education and financial support in order to adopt BMPs. This type of institutional assistance can increase the attractiveness of adopting a BMP, and directly affects the cost/benefit balance, thereby enhancing the BMP's profitability. Availability of education, communication, and demonstrations as part of extension services are also conditions required for adoption of new BMPs.

3.4.6.4 Funding availability and commodity prices

Discretionary operational capital or credit accesses are important conditions for adoption of a new BMP to take place. This is especially the case when large investment costs are needed for its implementation. Having available access to funding for investment related to a BMP is a condition under which farmers are more likely to adopt it.

Higher commodity prices can decrease the intensity with which farming is realized and it can leave space for BMP adoption. Higher commodities prices can also increase profit margins thereby allowing for investments in new BMPs. They can also provide a sense of stability, thus encouraging longer-term investments (Smithers and Smit, 1989). High input prices can also influence the adoption of conservation practices, particularly for water resources (Feder and Umali, 1993).

3.4.7 Lessons from the Literature Review of Agricultural Adoption of Innovations

There is a vast array of economic, sociological, psychological, agronomical, and health sciences literature pertaining to the adoption of agricultural innovations. The perspectives found therein are often multidisciplinary, and each piece carries with it, a unique set of models and assumptions (Pannell et al. 2006; Zilberman et al., 2012). These disciplinary studies are extremely important in advancing knowledge regarding the variety of factors influencing the adoption process. However, they provide limited and discontinuous understanding of the complex linkages between these factors.

Several authors reviewed factors affecting BMP adoption. Approaches used, include both cross-disciplinary (Pannell et al., 2006), and interdisciplinary (Duff et al., 1992; Stonehouse, 1996), perspectives and as well as an interdisciplinary approach. However, despite these differences in language and framing of specific disciplines, most findings are consistent with one another (Pannell et al., 2006). It is consistently reported in literature reviews of agricultural adoption, that the factors coming together to inform a decision, do so in configurations that vary depending upon the agricultural innovation being considered for adoption, also in addition to varying across biophysical, institutional and social settings.

Assuming it is more relevant to study the determinants of adoption with specific BMPs in mind, and within the proper and particular social and natural systems, there is room for specific knowledge growth. Some argue that the literature in this area has reached a saturation point. However, this is a narrow position, since only few attempts have been made to draw from multiple disciplines in designing the research approaches in this field. Such efforts can be rather beneficial in allowing one to find a parsimonious understanding of this field of study. At the same time, there are areas that still require investigation. An example is the influence of BMP perception on adoption. Another area of research rarely explored is the relevance of a farmer's social network in learning about a BMP and to what extent this network is instrumental in their decisions. The theoretical framework, pertaining to social network analysis, emphasizes the relational aspect of individuals to be seen as embedded in the social structures in which they operate. Under this theory, less importance is given to individual agents. Substantial work in the area of diffusion of innovations within social networks has been done in the area of public health (Valente 1996; Smith and Christakis, 2008). Applying the social networks lens has the potential to uncover other factors important to adoption of BMP.

Another issue reported in previous studies relates to the inconsistencies with which farmers' attitudes are being measured. Drawing from the Reasoned Action Approach Theory and Diffusion Theory, one can use the joint theoretical approach to help us better understand the constructs that need to be measured. Furthermore, it can support an understanding of the process and the distinction between direct and indirect factors influencing decision-making.

Perceived characteristics of agricultural innovations and more so their influence on the adoption decision-making process, has received limited attention. Recent findings highlight the importance of BMP perceptions. Farmers' perceptions of characteristics of the practices or technologies considered for adoption can have a significant role in their adoption. Hence, research studies should also focus on this aspect of adoption.

3.5 AGRICULTURAL POLICIES FOR BMP ADOPTION SUPPORT

Agricultural producers can influence society through the managerial choices they make within their production systems. In recent years, modern agriculture has been associated with a decline in the quality and quantity of natural resources. Examples include the eutrophication of lakes, soil erosion, inefficient water uses, air pollution, etc. These impacts are generally referred to as negative externalities, in the economics literature. Externalities are costs and benefits incurred/gained beyond those causing the effect (Anderson, 2010). Whenever they represent a cost to the society (diminish welfare), they are termed negative externalities (i.e., agricultural runoff leaving the farm and polluting drinking water sources). When they provide benefits (increase welfare), they are referred to as positive externalities (i.e., providing habitat for migratory birds on the farm). Two simple models, Figures 3.5 and 3.6, illustrate the link between externalities and social welfare.

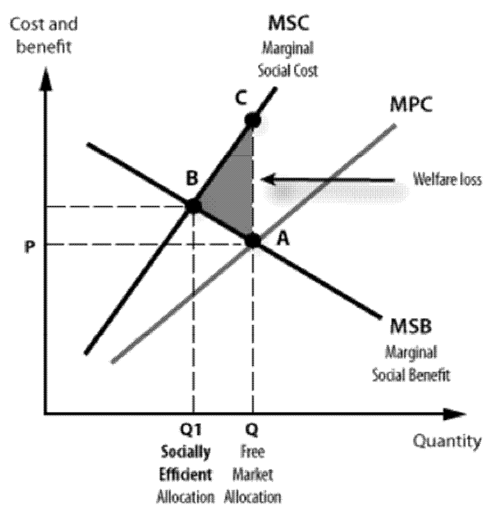


Figure 3.5. Negative Externality and Welfare Loss

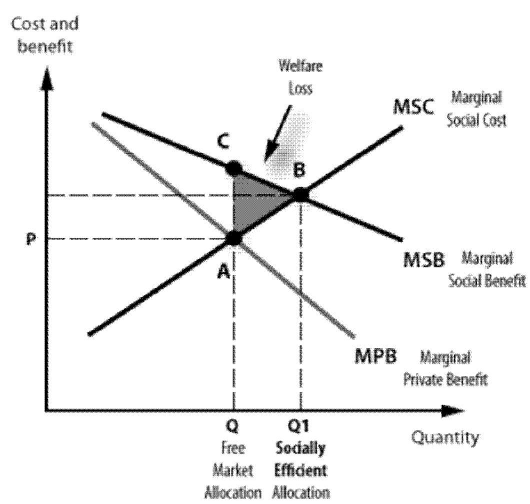


Figure 3.6. Positive Externality and Welfare Loss

Let us assume that a tomato grower currently produces a *Q* quantity of tomatoes and receives a market price *P* (refer to Figure 3.5). Let us assume now that in addition to tomato production, the farmer also contributes to the pollution of the lake located in the vicinity of his farm, through releasing agricultural runoff leaving his field. The costs of pollution are external to the agricultural production system and are imposed on the rest of the society. Acting as a rational agent in the market, the agricultural producer will not attempt to internalize those costs, unless incentivized to do so. If the quantity of commodity produced is directly correlated with the pollution, one can see in Figure 3.5 that the output of the commodity in this case is too large, too much pollution is produced, and a socially optimal allocation does not take place (adapted from Titenberg, 2006). When agricultural producers do not bear all the costs of production, markets fail to allocate resources efficiently and ultimately affect social welfare (Tietenberg, 2006). In this case, marginal external costs put a wedge between private marginal costs (MPC) and social marginal costs (MSC). The tomato grower will increase his commodity production, until the MPC equals the marginal social benefit (MSB). The shaded triangle ABC shows the welfare loss associated with tomato production. The socially optimal quantity of tomato production *Q1* is reached when the MSC equals the marginal social benefit (MSB) at a higher price. Figure 3.6 illustrates the case of positive externalities, where benefits accrue to society at large, rather than strictly the producer. In this case the benefits are under supplied, and the result is similar, a reduction in social welfare of ABC utils.

One way of achieving improvements in social welfare is through the internalization of costs or benefits by agricultural producers. Investment in improved practices and/or technologies could improve social welfare, by diminishing the off-farm effects related to agricultural production. However, undertaking such changes, generally, imposes costs on farmers, which they might not be willing to absorb given a certain market condition. In such cases, governmental intervention might be warranted. In order to better understand whether there is a need for governments to intervene, and what approach they should employ to restore a socially optimal agricultural production, one needs to better understand the costs and benefits these managerial changes impose both on the farm, as well as on the society. In the following section, focus is on policy tools and how they can be used to offset challenges faced by agricultural producers.

3.5.1 Agricultural Policy Tools

Policy tools or instruments are methods through which a government attempts to achieve policy objectives. They are designed to change the behavior of a targeted group of actors, either by encouraging actors to refrain from an activity or by convincing them to pursue or continue an activity that they would not otherwise pursue. There are generally three broad categories of instruments that policy makers can use in order to reach their objectives: command and control (i.e., performance standards, design standards, laws, etc.), economic instruments (i.e., taxes, payments, tradable permits, etc.) and advisory/information instruments (i.e., research and development, technical assistance/extension, labeling, community based measure, etc.)[3].

The choice of approach usually depends on several factors that are interrelated: problem definition, policy goals, targeted actors, public resource availability and efficiency. Accurate definition of the problem is crucial in the selection of instruments. For example, in the case of inefficient agricultural water consumption, if the issue is defined as an economic problem, farmers are free to use as much water as needed. This inefficiency can be corrected through pricing water or through placing a tax on its use. On the other hand, if inefficient water use is a social understanding problem, more likely moral suasion tools will need to be employed to reduce the lack of awareness. Water inefficiencies defined as developmental issues of the agricultural sector could be addressed with subsidies and funds for research and development, to foster the adoption of alternative technologies and practices, or the development of alternatives[4].

Instrument selection is determined by what the government needs to achieve -- the policy objective. For instance, if the objective is to improve the environmental condition of a particularly critical resource or a region, a more stringent regulation could achieve it. Weersink et al. (2002) explains that the choice of environmental policy within the agricultural sector is constrained by several variables specific to this sector: diffuse character of pollution sources (measurement and monitoring issues), as well as spatial and temporal heterogeneity of actors (different impact levels, different capacities and uncertain effects).

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[3] This discussion is based on notes taken while attending courses on Environmental Policy by Prof. Eric Massey at Free University of Amsterdam and Resource and Environmental Policy Analysis by Prof. Kenneth Belcher.

[4] This discussion is based on notes taken while attending courses on Environmental Policy by Prof. Eric Massey at Free University of Amsterdam and Resource and Environmental Policy Analysis by Prof. Kenneth Belcher.

This last issue ties into the importance of the actors in the government's selection of policy instruments, which may lead to the political acceptability of the decision maker's choice by agricultural producers. Weersink et al. (2002) noted that in the case of agricultural producers, farmers have been assumed to have the right to carry out "normal farm practices". For farmers to do otherwise would require that they be compensated. This is reverse of the polluter-pays principle, which is typically seen for other industries. Instead, an alternative avenue would be to employ a beneficiary-pays principle. This discrepancy in the selection of policy instruments, based upon tradition and industry specific attitudes, has notable implications for BMP adoption. It is common that when the polluter pays principle is established, negative incentives are more likely to be considered, whereas with the beneficiary pays principle in place, behavioral changes are more commonly achieved through positive incentives (Pannell, 2008).

Policy instruments come with transaction costs associated with their implementation. Public funds are limited, and a variety of projects/programs competes for them. While strict regulations can be very effective in tackling environmental problems, they can be costly (i.e., increased data needs for setting reference levels, modeling requirements, monitoring, enforcement, etc.). A common approach that is used to address this issue is to evaluate the trade-off between the effectiveness and the costs of a policy approach. In order to understand if a policy approach is cost-effective, there is a need to evaluate the environmental improvements provided by the policy against implementation costs. Weersink et al. (2002) noted that in the case of agriculture, such effects could be difficult to assess.

The choice of policy instruments can depend on many more factors than the ones described above and most often, they are used in combination with other instruments, since each approach has its own imperfections.

3.5.2 Agricultural Policy Tools in Canada: Cost-Share Program

In Canada, voluntary cost-share programs have been implemented to provide positive incentives for a set of practices or technologies, thereby making BMP more attractive to agricultural producers. Payments are awarded based on farmer's participation in the program. Improved environmental outcomes are implicitly expected from the adoption of these BMP, but no specific requirements are made in relation to these expected environmental performances

(Weersink et al., 2001). In Ontario, agricultural producers are required to complete an Environmental Farm Plan, in order to be eligible for cost-share programs (OSCIA, 2016).

Agricultural producers are heterogeneous both in terms of farm (biophysical, financial) and personal characteristics. Adoption of a BMP will result in different impacts on the costs and benefits for each farm. Payment programs are commonly provided over broad geographic areas (Weerink et al., 2001), without taking into consideration the important distinction between the characteristics of a farm and the farmer. Such broad-spectrum policy application creates problems of overall efficiency. These inefficiencies are borne out either through a farmer's failure to adopt BMPs because of insufficient incentives, or through farmers adopting BMPs while using public funds. The latter case represents an inefficiency when incentives were already great enough for a farmer to adopt a BMP without the aid of additional financial support. The implication of inefficiencies in broad-spectrum policy application is that a more targeted approach in terms of geographical area and agricultural producers can be more beneficial. The downside is that targeting can be more expensive, which explains the tradeoff approach used. This issue of policy scale and resolution once again emphasizes the importance of properly estimating the private costs and benefits associated with the adoption of particular BMPs in specific locations (Weersink et al., 2001; Knowler & Bradshaw, 2007; Pannell et al., 2006).

One of the main goals of delivering cost-share programs for agricultural producers is to improve environmental conditions. In Canada, evaluations of the effectiveness of BMPs in tackling environmental issues have been conducted with limited success, often yielding inconclusive results. Recent reports indicate that large variations across spatial scales at which these BMP are adopted, together with time lags (between adoption and effects), increase the difficulty of evaluating BMP environmental impacts (Council of Canadian Academies, 2013).

The effectiveness of the cost-share program is closely linked to the environmental performance of the proposed BMPs. Without a better understanding of the BMP effectiveness, the program's effectiveness itself could be questioned. Cost-effectiveness uncertainties of the cost-share programs are also related to the issue of uncertainty of BMP effects. Voluntary cost-share schemes are popular policy approaches within the farming communities, but they can reduce the effectiveness of governmental interventions. For example, agricultural producers that have the highest negative impact on the environment can choose not to participate in the program, thereby making such programs somewhat ineffective in tackling certain environmental issues. Targeting key agricultural producers might be a more viable approach in tackling this issue.

Another weakness of the cost-share program is the criterion used for funds allocation. Instead of allocating these financial resources based on environmental performances, agricultural producers are given the financial assistance based on their participation in the Environmental Farm Plan. This allocation system raises issues related to efficiency, effectiveness, and cost-effectiveness of the program. Some solutions proposed to overcome this issue are the allocation of public funds based on the environmental performance of the BMP (i.e., payments for EG&S produced) (Baird, 2012), or through improved benefits targeting (Engel et al., 2008). Both alternatives come with increased information needs, and costs of implementation and monitoring, which are important for performance-based payments.

3.6 SUMMARY

This chapter provided an account of the thematic literature review conducted to inform the design of the current study. Agricultural producers can use BMPs as adaptation strategies to enhance the resilience of their farms. However, the adoption of new practices and technologies depends on the feasibility of the proposed BMP. Furthermore, this section highlights the fact that within Canada, federal and provincial governments through cost-share programs support these BMPs. These programs provide financial subventions to producers to incentives them to adopt improved practices and technologies on their farm.

To evaluate the feasibility of a BMP, there are different analysis approaches one can take. Positive farm modeling approaches allow for evaluative types of assessments, whereas normative approaches require an objective function to be specified. Stochastic farm models are more comprehensive because they can better account for risks and uncertainties, however deterministic models are easier to construct and can be a good starting point in an analysis. In this section of the chapter, a discussion of the difference between whole and partial farm analyses, as means of systematically evaluating the profitability of a new investment, was also undertaken. From this literature, one may derive the conclusion that while a whole farm budget analysis is a more complete analysis, in cases where the change on the farm is not an extensive one and does not impact the entire farm, a partial budget analysis can be a suitable tool of analysis to evaluate the profitability of a new investment.

Rogers' Diffusion Theory, Ajzen, and Fishbein's Reasoned Action Approach were presented in this chapter as well, as theoretical frameworks that can be jointly used to identify factors that support or hinder adoption. The joint use of these two theories, is thought to provide a more comprehensive understanding of the decision-making process around adoption of BMPs. A summary of the vast adoption literature is provided, with a focus on the four main categories of factors: farmer, farm, BMP, and context characteristics. This section concludes with a summary of lessons learnt from reviewing the adoption literature.

CHAPTER 4. RESEARCH METHODOLOGY

4.1 INTRODUCTION

This chapter describes the methodological approach used to provide evidence for the study objectives. In the first section (Section 4.2), the overall methodological approach is described, together with the research design used to address the research questions of this study. The second section (Section 4.3) contains information regarding the geographical locations of the study areas, together with additional information concerning agricultural production systems and agricultural producers in these locations. In the third section (Section 4.4), details about data collection procedures are provided, including the description of survey instrument development, selection of procedures involved in data collection, and sample characteristics. The fourth section (Section 4.5) highlights relevant characteristics of the approaches to data analysis used. It covers both the methods associated with agricultural projects evaluation, and the analytical techniques used for modeling adoption behavior of agricultural producers. The last section (Section 4.6) of this chapter provides a summary of the chapter.

4.2 RESEARCH DESIGN

As noted in Chapter 1, the purpose of this study was to assess the economic impact of adopting three distinct water management systems (referred to as the BMPs) by fruit and vegetable growers in Ontario and Québec. Associated with this objective was the need to identify factors that influence producers' adoption behavior for these BMPs.

To meet the study objectives a mixed methodological approach[5] was used. This approach involved a combination of case studies and in-depth interviews for data collection. Case studies

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[5] "Mixed methods research is a research design with philosophical assumptions as well as methods of inquiry. As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative approaches in many phases in the research process. As a method, it focuses on collecting, analyzing, and mixing both quantitative and qualitative data in a single study or series of studies. Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone." Creswell and Clark (2017, p. 5).

represented the qualitative inquiry approach used for this research. Case study farms were representative of commercial farms in a selected region that produced the same product – tomato, cranberry and onion. This qualitative approach provided information on the performance of each BMP, as well as farmers' perceptions of benefits, costs and overall opinion of the BMP. In-depth interviews were carried out with agricultural producers in three locations: Leamington Ontario, Saint-Louis-de-Blandford, Québec, and to a lesser extent in Saint-Patrice-de-Sherrington, Québec. The purpose was to explore in depth, the effects of various specific technologies and practices on these farms and to gather growers' opinions about these BMPs.

The above set of information was used to develop the quantitative methodology for the study. For this purpose, a cross-sectional survey designed to understand growers' attitudes and perceptions regarding specific BMPs were undertaken. These data were collected from a sample of fruit and vegetable growers in southern Ontario and Québec. The purpose of the quantitative analysis was to identify factors that may influence agricultural producers' adoption decisions. Data were collected using a web-based survey, distributed to local growers.

4.3 RESEARCH SITES

This study is based on three research sites located in southern Québec and Ontario. A summary of these sites is provided in Table 4.1, whereas their locations are shown in Figure 4.1.

Table 4.1. Summary of Salient Features of Research Sites

Name of the Research Site	**Province of Location**	**Commodity Produced**	**Selected BMP for water management**	**Baseline BMP**
Leamington	Ontario	Tomato	Subsurface drip irrigation	Surface drip irrigation
Saint-Louis-de-Blandford	Québec	Cranberries	Sprinkler irrigation and water table control	Sprinkler irrigation and no water table control
Saint-Patrice-de-Sherrington	Québec	Onions	Sprinkler irrigation	No irrigation / Dryland production

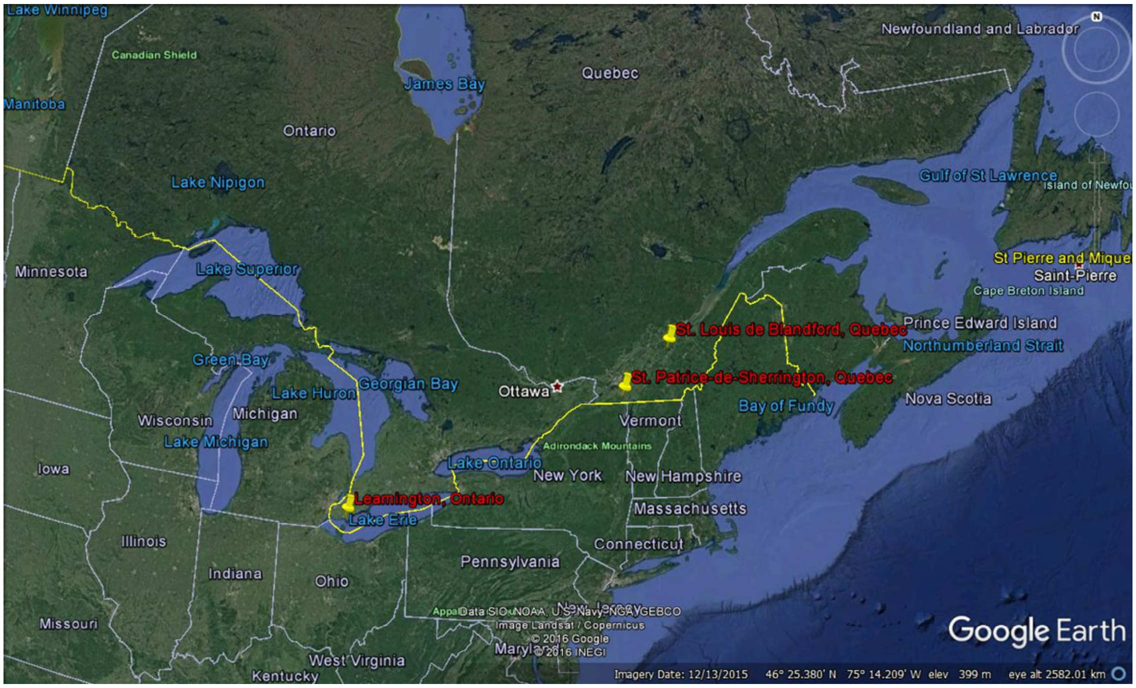

Figure 4.1. Map of Eastern Canada showing Research Sites

4.3.1 Case Study 1 - Tomato Production in Leamington, Ontario

The Leamington research site is in the Essex County, Southwestern Ontario. This farm is representative of a large commercial tomato production operation in this County. The size of this farm is approximately 1,000 acres. The farm's land allocation is divided between tomato production, which occupies approximately 10% of the total farmland, seed corn (10%), corn (10%) and soybean (65%). The tomato cultivar grown on this farm is Heinz 9553, a product intended for processing markets. The crop is in a two-year rotation cycle, with either seed corn or corn. The soil type is loamy sand.

On this farm, irrigation is used only for tomatoes, with 50% of the area under tomato production being irrigated using surface drip irrigation and the other half using a subsurface drip irrigation system. The main water source for irrigation is Lake Erie -- brought through Leamington Area Drip Irrigation Incorporation (LADII). This water is supplemented by that available in the municipal ditch system.

At this location the BMP under evaluation was subsurface drip irrigation, which was compared against the existing technology used – a surface drip irrigation system. Details on the experimental design of the biophysical team, together with additional information regarding measurement are provided in Edwards (2014). This team set up in-field experiments and recorded water use, fertilizer type and applications, soil water capacity, tomato yields, irrigation scheduling, and greenhouse gas emissions coming from the soil. In addition to these data, economic data on the farm and the BMPs were collected through an in-depth interview with the agricultural producer.

4.3.2 Case Study 2 - Cranberry Production at Saint-Louis-de-Blandford, Québec

Another research site was a cranberry farm located in Saint-Louis-de-Blandford, Centre-du-Québec region, in Québec. The farm has approximately 1,400 acres dedicated solely to cranberry production. On this farm, the Stevens cranberry variety is grown, which is the most predominant cultivar grown in North America. The cranberry production takes place in rectangular basins, also referred to as cranberry beds, which are half a meter deep. This cranberry bog basin dimensions are approximately 50m by 500m (150 feet x 1500 feet); the original soil was excavated and was replaced by sandy soil that have better drainage characteristics. Other producers in the region have similar production layouts and practices.

Drainage tiles were installed across the entire production area. Within each basin, there are three drainage tiles located at 18’’ underneath the soil surface. Drainage is also achieved via surface ditches, located at each edge of the cranberry fields. The main water source is the Becancour River. Irrigation in cranberry production has several purposes. Sprinkler irrigation is used to meet plants’ water requirements during the summer, and for plant frost protection in late fall and early spring. In order to accurately meet the plants water requirements, irrigation scheduling is done with the use of tensiometers – devices that provide soil moisture readings.

At this site, two water management systems were evaluated: sprinkler irrigation and subirrigation. The latter is a dual-purpose water management system, which provides both irrigation and drainage. Additional water for irrigation can be supplied through the same pipes that are used for drainage. Optimal use of subirrigation is achieved when the water table is accurately managed. The existing drainage system for cranberry production was modified, to make subsurface irrigation a feasible option. Control structures and pumps required to move the water in and out of each cranberry basin were required for subirrigation. In some cases, the modification of the current drainage system involved only the installation of additional pipelines. Pelletier et al. (2013, 2015, and 2016) have provided additional information on the in-field research design at this site. Like the tomato farm case study, data were obtained from the biophysical research team and from the agricultural producer.

4.3.3 Case Study 3 - Onion Production Saint-Patrice-de-Sherrington, Québec

The third research site was in Saint-Patrice-de Sherrington, in Montérégie, Québec. The farm is approximately 1,500 acres; about 350 of which (23%) are allocated to the production of dry onions. This case study farm uses a 2-year crop rotation in its production cycle. In the first rotation onions and carrots are grown, which is followed by spinach and lettuce. On this farm, onions are irrigated using a sprinkler system. The water source for irrigation is groundwater -- a well located on the farm. Furthermore, a reservoir was recently constructed on the farm to supplement irrigation water needs. The soil on the farm is predominantly rich in organic matter. At this research location, the BMP under evaluation was sprinkler irrigation.

4.4 DATA COLLECTION METHODS

Data for this study were collected using two distinct groups of survey instruments. For the individual farm case studies, semi-structured interview instruments were developed, while for collecting data from regional producers, structured questionnaires [6] were developed. In the following section, a description of these survey instruments is provided, together with information on the development of these instruments.

4.4.1 Farm-level Data Collection: Semi-Structured Interviews

Data for individual case studies in Leamington, St-Louis-de-Blandford and Sherrington were collected using semi-structured interviews of agricultural producers. A questionnaire was developed for each case study, which was subsequently tested. The one for tomato production is shown in Appendix A. Each questionnaire included six sections: (1) Farm background information; (2) Costs and benefits of the adoption and the cost of investment; (3) Production costs; (4)

[6] Semi-structured interviews are the in-person data collection strategy, which contain mostly open-ended questions, but they can also contain closed-ended ones as well. The questions are used to guide the conversation; however, the respondent might bring up new areas of interest. Structured questionnaires are sent to respondents in written form, and contain close-ended questions.

Motivations, barriers and perceptions; (5) Personal information; and (6) Sales and net worth of the producer.

The questionnaires were partially based on governmental publications, especially on details of production practices and cycles for each crop. Budgets containing costs of production for various fruits and vegetables were consulted for questionnaire development, together with publications on the cost of investment, and discussions with agricultural equipment providers. The sections of the instrument containing demographic information (Parts 1, 5 and 6), were guided by Statistics' Canada agricultural census questionnaire. In the testing phase of the questionnaire, feedback from peers and industry experts were incorporated. The survey was first tested using a local horticultural grower.

McGill's biophysical team at the outset of the Agricultural Greenhouse Gases Project (AGGP) realized the recruitment of the respondent for the case study. In this selection, biophysical characteristics of the farms, crops grown, and water management system used were considered. The initial intent was to conduct in-depth, face-to-face interviews with three producers. The tomato grower located in Leamington, Ontario, the cranberry grower and St.-Louis-de-Blandford and the dry onion producer in St.-Patrice-de-Sherrington. The case study producers at two sites (Leamington and St.-Louis-de-Blandford) data were collected using face-to-face interviews. However, for the third case study, data collection involved partial face-to-face and partial through e-mails. Furthermore, full information required from the dry onion producer could not be obtained. For this reason, the information provided was supplemented with secondary data for that case study. These data were used to conduct the three case study analyses, which evaluated the profitability of the three proposed BMPs.

4.4.2 Structured Questionnaires for Regional Agricultural Producers

Data collection for identification of factors influencing the adoption of BMP and for modeling agricultural producers' decision-making process was based on the use of structured questionnaires using web-based technology. A questionnaire was developed for each case study, which was translated into French, and pilot tested. An example for the tomato case study is shown in Appendix B. All surveys were created using Fluid Surveys, a web-based survey programming tool. Each survey instrument included six sections: (1) Description of the improved water management system; (2a) Adoption: motivations, barriers and perceptions; (2b) Non-adoption:

motivations, barriers and perceptions; (3) Opinions: farmer-environment interactions; (4) Policy changes for adoption (only for non-adopters); (5) Farmer personal information; and (6) Farm background information.

The description of the improved water management systems was distinct for each one of the growers' group. The figures below show the information that was presented to each of the producers' group – tomato (Figure 4.2), cranberry (Figure 4.3) and dry onion producers (Figure 4.4). The BMPs presented to regional producers are similar but not all the same as the ones investigated through the case studies. Differences exist in terms of the BMPs' characteristics and effects. A BMP that was different was subirrigation in cranberry production. In the farm case study, subirrigation was not used, even though the growers' system had the technical capacity. The information provided to regional growers regarding the characteristics of the BMP was derived from secondary literature and findings coming from the case study farm. Before presenting the survey to producers, experts carefully reviewed the information.

As you might already know, subsurface drip irrigation is a low-pressure, low-volume system, with drip tubes placed below the soil surface at a depth of approximately 15-20 cm (depending on soil type, crop and tillage practices). Previous studies found that subsurface drip irrigation in tomato production has the following characteristics:

Characteristic	**Costs and Benefits Details[1]**
Capital investment cost	• 1,500-2,000 $/acre[2]
Life expectancy	• 10-15 years[3]
Tomato yields	• Increased by 8% using subsurface drip as compared to surface drip • Increased by 25% using subsurface drip as compared to sprinkler • Increased by 60% using subsurface drip as compared to non-irrigation
Annual operating costs	• Decreased annual costs by 40-45% under subsurface drip irrigation as compared to surface drip irrigation[4]
Uniform ripening	• Green tomatoes percentage reduced by 16% under subsurface drip, as compared to non-irrigation
Nutrients use	• Increased efficiency of both N and P use under drip irrigation, as compared to non-irrigation
Water use	• Increased efficiency by 32% under subsurface drip as compared to non-irrigation
Greenhouse gas emissions	• Tomatoes grown using subsurface drip irrigation have 14-18%[5] lower GHG emissions than tomatoes grown with surface drip irrigation
Other	• Less labor needed with subsurface drip when compared to surface drip • More specialized machinery implements for subsurface drip in comparison to surface drip • Increased managerial decision making • Increases field accessibility • Increased need for accuracy when installing the subsurface drip as opposed to surface drip, sometimes additional resources are needed (i.e. GPS)

[1] Details are only for reference; they vary depending on the characteristics of your own farm, the subsurface drip irrigation system selected, etc.
[2] The assumption is that there was no previous irrigation system in place;
[3] Based on the most expensive part to replace from the irrigation system;
[4] Based on the assumption that the subsurface drip tape is left under the ground for 3-4 years, whereas the surface drip tape removed each year.
[5] Based on a case study farm located in Leamington, Ontario

Figure 4.2. Information Provided to Tomato Producers Prior to Survey

Subirrigation is a dual-purpose water management system that provides both irrigation and drainage. Additional water can be supplied through the same pipes that are used for drainage. Optimal use of subirrigation is achieved when the water table is accurately managed. Modifying an already existing drainage system, in cranberry production, so that it allows for subsurface irrigation could be a feasible option. Control structures and pumps required to move the water in and out of each cranberry basin, are required for subirrigation. In some cases the modification of the current drainage system might involve only the installation of additional pipelines. Sprinkler irrigation is still expected to be used in spring and late autumn to protect cranberries against frost and in summer for heat protection. For an optimal use of subirrigation for water management in cranberry production, several requirements should be met:

i. Water table depth maintained between 0.6 and 0.7 m
ii. Irrigation should be started when soil water tension reaches between 7.0 and 8.0 kPa
iii. Water table management informed by accurate measuring devices (i.e. tensiometer);
iv. Unobstructed drainage system, equipped with control structures and a sufficient distance between the drains;

Previous studies found that subirrigation with water table control - in cranberry production, has the following characteristics:

Characteristic	Costs and Benefits[1]

Capital investment cost	• Range could be on average between 250 - 1450 $/acre[2], depending on your farm
	  ○ Tensiometers: 128 – 362 $/acre
	  ○ Additional pipelines: 526 – 769 $/acre
	  ○ Drain control structure and ditch rehabilitation: 404 – 485 $/acre
	  ○ Drain cleaning: 97 – 122 $/acre

Life expectancy	• 20 years[3]
Cranberry yields	• Increase in cranberry yields could be of 51% under subirrigation with water table control as compared to sprinkler irrigation and no water table management[4]. This increase in yields was due to improved drainage, which was needed for using sub irrigation in an optimal way. In situations where the drainage system is well functioning, it is possible that subirrigation might have no effect at all on yields[6].
Energy costs	• A reduction of 84.4% in annual energy costs related to irrigation under subirrigation with water table control as compared to sprinkler irrigation and no water table management[4].
Water use	• Water use was reduced by 84.4% as well when subirrigation and water table control was used as compared to sprinkler irrigation and no water table control[4].
Greenhouse gas emissions	• There are no significant differences between greenhouse gas emissions from cranberry fields under different soil water scenarios throughout most of the growing season. • For the most part of the growing season the cranberry fields were a sink of methane, however when the fields were flooded, due to over irrigation, during harvest and the spring snowmelt, they became a source[5].
Other	• Less labor needed for subirrigation when compared to sprinkler irrigation • Increased managerial decision making related to irrigation

1. Details are only for reference; they vary greatly depending on the characteristics of your own farm
2. Based on Jabet (2014), research of economic profitability of different water management practice in cranberry production, St. Louis de Blandford, Quebec
3. Based on the most expensive part to replace from the system;
4. Based on Pelletier (2014), case study on 30 acres, including 2012 and 2013 growing seasons, in St. Louis de Blandford, Quebec
5. Based on Grant (2014), case study including 2011 and 2012 growing seasons, in St. Louis de Blandford, Quebec
6. Based on Vanderleest (2014), case study including 2013 and 2014 growing seasons, Winsconsin

Figure 4.3. Information Provided to Cranberry Producers Prior to Survey

Previous studies found that sprinkler irrigation and the use of tensiometers for triggering irrigation - in onion production, has the following characteristics:

Characteristic	Costs and Benefits[1]
Capital investment cost	• Depending on your farm the investment could involve[2]: o Tensiometers: 128 – 362 $/acre o Sprinkler irrigation system: 1,400 $/acre o Water reservoir 150-300 $/acre
Life expectancy	• 15 years[3]
Onion yields	• A significant increase was obtained under optimal irrigation conditions for the jumbo size compared to unirrigated plots – irrigation triggered based on tensiometer readings. Under sprinkler irrigation an yield average of nearly 17 mg/acre compared with the unirrigated plots an average of 5 mg/acre[4].
Energy costs	• An increase of 67.5% in annual energy costs related to irrigation under sprinkler irrigation as compared to no irrigationt[4]. Tensiometers were used for triggering irrigation.
Water use	• Water use was increased by 67.5% as well when onons were irrigated as compared to no irrigationl[4]. Tensiometers were used for triggering irrigation.
Greenhouse gas emissions	• There are no significant differences between greenhouse gas emissions from onion fields whether irrigated or not
Other	• More labor needed for irrigation when compared to no irrigation • Increased managerial decision making related to irrigation • Frost protection • Increased onion quality with irrigation • Prevent soil erosion

[1] Details are only for reference; they vary greatly depending on the characteristics of your own farm
[2] Based on CRAAQ 2008 and Jabet (2014), research of economic profitability of different water management practice in cranberry production, St Louis de Blandford, Quebec
[3] Based on the most expensive part to replace from the system;
[4] Based on Rekika (2014), case study including 2008 and 2009 growing seasons, in Sherrington, Quebec
[5] Based on Grant (2014), case study including 2011 and 2012 growing seasons, in Sherrington, Quebec

Figure 4.4. Information Provided to Dry Onion Producers Prior to Survey

The data collected from the individual case studies was supplemented by that in governmental factsheets and research reports. Parts 2, 3 and 4 of the questionnaire, were developed based on the theoretical foundations provided by two prominent theories in adoption decision-making: Rogers' Diffusion Theory (Rogers, 2003) and Theory of Planned Behavior (Fishbein and Ajzen, 1977). In addition, previous empirical research on improved water management practices or other beneficial management practices were used to formulate the questions in the above noted three parts of the questionnaire. Like the case study questionnaires, the sections containing demographic information (parts 5 and 6) were guided by Statistics' Canada agricultural census questionnaire.

In the testing phase, the questionnaires were distributed to processors, local agricultural producer association directors or agronomists, regional governmental experts, other peers and professors at Laval and McGill Universities (those studying the same technologies and practices). Their feedback was incorporated first. The revised questionnaire was tested with the help of several agricultural experts[7]. Two of the surveys (for cranberry and onion producers), were translated to French. After the initial translation, the translation was checked and corrected by native French speaking students, and then as a final step, by students and professors at McGill University and Laval University[8].

4.4.2.1 Measures of Quality: Reliability and Validity of the Survey Instrument

Data collection using survey tools inevitably contains certain amount of error; however, these errors can be minimized in a way that the information collected provides a fair representation of reality (Fink and Litwin, 2003). In survey-based research, the errors can be either random errors or measurement errors. In this section, the focus is on the latter type of error -- measurement error, since the other one is related to sampling design and will be addressed in the following discussion.

Measurement error reflects the precision of the survey instrument. There are different ways to measure the quality of the research tool. Reliability is a statistical measure of reproducibility or stability of the data gathered with the survey instrument. To ensure the instrument's reliability, established survey tools were used as guidelines[9]. To ensure internal consistency, Cronbach's coefficient alpha was calculated[10]. With one exception, which can be explained by the multi-

[7] The people involved with testing the surveys were numerous. For the tomato producer survey, the following individuals made a contribution: Janice LeBoeuf - OMAFRA, Vegetable and Crop Specialist; Karl Evans - Conagra Foods, Production Manager; Tim Suitor - Highbury Canco (previously at Heinz), Steve Lamoure - SunBrite Foods, Field Advisor; John Molenhuis - Cost of production specialist OMAFRA. For the cranberry producers' survey, the following individuals contributed: Jean Caron - NSERC/Hortau Industrial Research Chair in Precision Irrigation; Vincent Pelletier - Researcher at Laval University, focusing on the study of improved water management systems in cranberry production; Marie Bieler - Agronomist and Project Manager, Atoka/Canneberges Bieler; Pierre Deland - Agronomist, Ocean Spray; Simon Bonin - Agronomist, Fruit D'Or. For the development of the onion producers survey the following individual were contacted and made a contribution: Jean Caron - Laval University; Mario Leblanc - Agronomist, MAPAQ; and Joann Whalen - Professor at McGill University.

[8] Professors Joanne Whalen and Jean Caron, from University of McGill and University of Laval, respectively, provided support in the translation phase of the surveys. Students Vincent Pelletier and Hicham Benslim also helped with the correction of the French version of the survey.

[9] Babbie and Benaquisto (2009, p. 141) describe the use of survey standards to ensure reliability but they also mention some of their limitations. Major caveat being that a wide use of a tool is generally a good indicator of reliability but not always.

[10] It is calculated to determine the extent to which items build to describe the same construct, a way of assessing the internal consistency of a scale. "In addition, reliability estimates show the amount of measurement error in a test. Put simply, this interpretation of reliability is the correlation of test with itself. Squaring this correlation and subtracting from 1.00 produces the index of measurement error. For example, if a test has a

dimension of the question, the values of this coefficient were high, indicating good reliability. More details on this calculation are provided in Appendix C.

Besides reliability of survey research methods, the other measure of quality of measurement is validity (Babbie, 2010). This can be simply defined as the extent to which a survey accurately assesses the concepts it intended to measure (Babbie, 2010; Fink, 1995). For the study questionnaires, face validity was ensured with the help of various peers who reviewed the instrument[11]. Furthermore, the questionnaires' review by researchers and agricultural experts ensured that construct and content validity measures were met as well.

4.4.2.2 Sampling Design, Respondent Recruitment and Collection Procedures

Data were collected for a sample of producers. However, the election of these producers was different for the three regions. While for tomato producers, the sample was drawn only from the two counties, for cranberry and onion producers' surveys the samples were drawn from the entire province of Québec. In 2011 there were a total of 228 tomato producers[12] in the Essex and Chatham Kent counties, and 1,422 across the province of Ontario (Statistics Canada, 2011). Across Quebec, in 2011, there were 72 farms that reported growing cranberries, while 358 farms reported growing dry onions (Statistics Canada, 2011).

Given the small number of each of the growers, it was not possible to use a random sampling method. The sample selection technique used in this study was nonprobability sampling. Several attempts were made to reach as many producers as possible, as described below:

Southern Ontario tomato growers' recruitment[13] was realized with Janice LeBoeuf's support, an employee of the OMAFRA. The initial phase involved getting in contact with three of

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reliability of 0.80, there is 0.36 error variance (random error) in the scores (0.80×0.80 = 0.64; 1.00 – 0.64 = 0.36)" (Tavakol and Dennick, 2011).

[11] Face validity involves a review of the survey by "untrained" individuals. It is an un-rigorous way to validate the survey and thus some researchers do not accept this as a measure of validity Fink and Litwin (2003, p.32).

[12] This number does not reflect the recent changes brought by the closure of HJ Heinz Company in mid-2014. It has been estimated that approximately 40% of the producers in the Leamington area are no longer growing tomatoes for processing.

[13] An initial attempt was made to distribute the survey through Ontario Processing Vegetable Growers Association (the organization was identified as the leading group having access to most growers); however, the Board of the organization refused due to the negative impact on the region caused by Heinz's closure.

the regional processors, from Highbury Canco, ConAgra Foods and Sun-Brite. With their help, the survey was distributed to 61 producers via e-mail. In addition to this, the survey was advertised by OMAFRA at their annual Tomato Day, where 100 producers attended. OMAFRA also tweeted the link to the survey and devoted a section on one of their websites – "ON Vegetables" to further promote the survey.

In Québec, cranberry growers' recruitment[14] was realized with the support of several regional experts -- Marie Bieler (Atoka), Pierre Deland (Ocean Spray), Simon Bonin (Fruit D'Or) and Isabelle Drolet (CETAQ). Approximately 80 producers were contacted.

In addition, in Québec, onion growers' recruitment was realized with the help provided by Mario Leblanc at MAPAQ, who distributed the study survey to 47 onion producers across Québec. Furthermore, Catherine Turgeon from UPA, supported the distribution of the survey, by e-mailing 42 producers in Montérégie. Because of some possible overlap between the two surveys, an accurate estimate the total number of producers reached cannot be made.

Agricultural producers in Ontario and Québec, involved in tomato, cranberry and onion production were surveyed in June 2016, November 2016 and March 2017, respectively. The scope of the survey was to assess growers' opinions regarding their adoption decision related to specific BMPs and their perceptions of these proposed practices and technologies. All respondents were contacted by e-mail. A reminder was sent to them after two weeks from the date of the original message. Based on available data, an estimated 210 growers were contacted[15]. The overall response rate was 35% (with 51% for tomato growers, 46% for cranberry producers and only 11.5% for onion growers).

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[14] A similar strategy to the one used in Ontario was followed here. Initially the APCQ was targeted as the better alternative to distribute the surveys, since they had the contact information of most growers in the region. However, they refused to distribute the survey on the basis that the growers would be burdened.

[15] This was based on the assumption of an overlap of 50% on UPA's growers' list with MAPAQ's.

4.4.2.3 Sample Characteristics

For this research, data were collected from 70 farms – tomato (39), cranberry (19) and onion (12) farms, as shown in Table 4.2. Most participants were tomato growers, representing approximately 17% of the regions' growers, based on the number of tomato growers in Essex and Chatham Kent counties. Cranberry growers completing the questionnaire accounted for over 27% of Québec's growers. In addition to tomato and cranberry growers, 12 onion agricultural producers also participated in the study, accounting for over 3% of Québec's onion producers.

Table 4.2. Number of Farms in the Population and in the Sample

Farm type	Population	Sample	% Sample from Population
Tomato Farms	228	39	17.11%
Cranberry Farms	72	19	26.39%
Onion Farms	358	12	3.35%
Total Farms	**658**	**70**	**10.63%**

To test whether the sampled farms are representative of their respective population, key farm characteristics – farm size, area dedicated to a specific crop, and land ownership, for each of these farms were estimated. The overall average farm size in the sample was approximately 949 acres, along with a wide range – a minimum of 2.5 acres and a maximum of 4,500 acres. Figures 4.5 to 4.7 show distribution of farms by size for the three groups.

Across different fruit and vegetable farms, there were differences in average farm size, as shown in Table 4.3. Tomato and onion farmers, who were included in the survey, had, on average, higher farm size than regional means – average tomato farm size in the population was 489 acres, whereas the sampled farms average was 1,171acres. The sample average for cranberry operations of nearly 443 acres was slightly smaller than the regional average of 505 acres.

In terms of the area dedicated to each crop, the sample is more homogeneous. Tomatoes were, on average, planted on 195 acres, cranberries on 193 acres and onions on 179 acres, which accounted for respectively, 16%, 47% and 17% of the total area of the farm. These proportions are slightly lower than the regional average (24%) for tomatoes, higher for cranberry (22%), and similar for onions (18%).

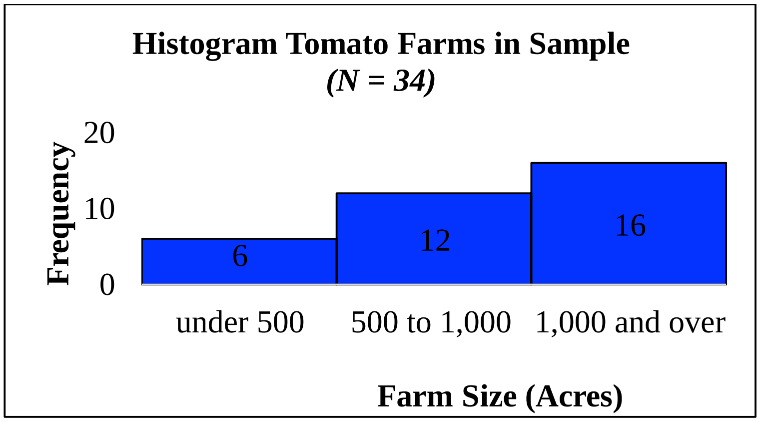


Figure 4.5. Histogram showing sample Tomato Farms by Farm Size

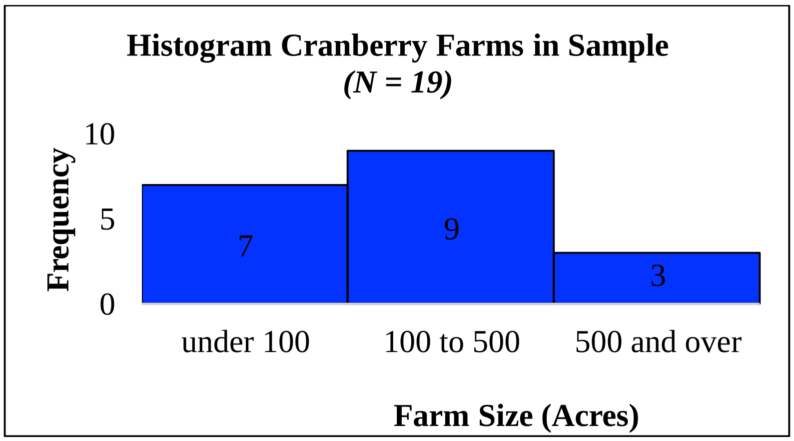


Figure 4.6. Histogram showing sample Cranberry Farms by Farm Size

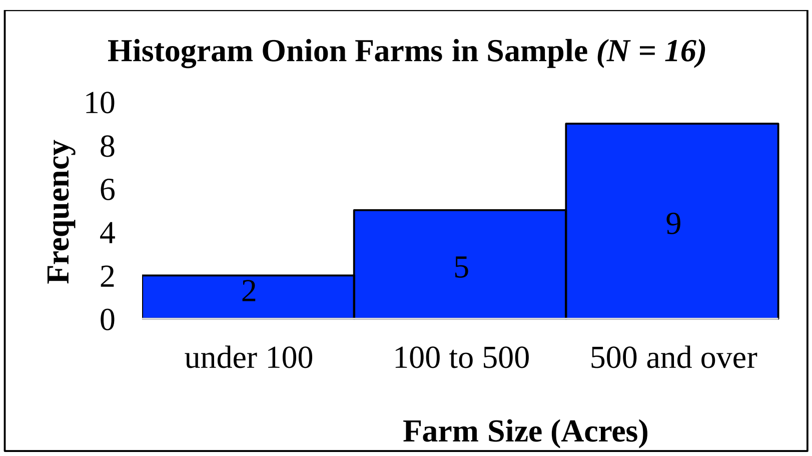


Figure 4.7. Histogram showing sample Onion Farms by Farm Size

Table 4.3. Sample and Population Physical Characteristics: Farm Size, Crop Size and Ownership (acres)

Farm Characteristic	**Population Average**	**Sample***					
		M	**SD**	**CV**	**Min**	**Max**	**N**
Sample Farm Size		949	970	1.02	2.5	4,500	70
Tomato	489	1,171	851	0.73	8.65	3,500	39
Cranberry	505	443	757	1.71	25	3,300	19
Onions	163	1,028	1,355	1.32	2.5	4,500	12
Sample Crop Size		195	328	1.68	0.6	2,400	70
Tomato	116	193	372	1.93	1	2,400	39
Cranberry	111	209	326	1.56	25	1,200	19
Onions	29	179	148	0.82	0.6	400	12
Sample Owned Land		674	765	1.14	0	4,275	70
Tomato	273	725	500	0.69	0	1,961	39
Cranberry	487	399	754	1.89	6.25	3,300	19
Onions	150	942	1,288	1.37	2.5	4,275	12

* M = sample average; SD = standard deviation; CV = Coefficient of variation; Min = Lowest value in the sample; Max= Highest value in the sample; N= No. of observations.

In addition, in Table 4.3, the average amount of owned land is shown, with averages varying depending on the crop grown. The percentage of the owned land from an average farm is 62% in the case of tomato growers, 90% for cranberry growers, and 92% for onion producers. These figures are like the ones reported by Statistics Canada (2011), where tomato growers own on average 56% of their land, cranberry growers 96% and onion producers 92%. Physical characteristics of farms in the sample and in the population are also shown in Table 4.3.[16]

[16] The sources of information for farm population data, were national (Statistics Canada, 2011) and regional statistics institutions or associations (MAPAQ, 2016; APCQ, 2019).

In terms of economic characteristics, the farms in the sample had higher sales than the farms found in the study regions. Across the surveyed farms, the most frequent group of sales for tomato, cranberry and onion producing farms was those selling over $1,000,000, meaning that larger farms were over represented in the sample.

The typical age of the sample farmers was between 35-54 years, which is close to the average age of 50 years for onion, tomato, and cranberry producers in Ontario and Québec. In terms of education, more frequent in the sample were producers who have a College or Technical Degree, which is also like data for the regional population.

4.5 DATA PROCESSING AND ANALYSIS

In the next section of this chapter, first the steps taken to conduct the farm level analysis are described, which include assumptions made at each step and details regarding the data sources used for this evaluation. Next, the steps involved in building the logistic and ordered logistic regression models is provided, which were used to explain adoption decisions and perception of the BMP as a better alternative.

4.5.1 Farm Level BMPs Evaluation

The farm level evaluation for the three case studies – Leamington, Saint-Louis-de-Blandford and Saint-Patrice-de-Sherrington, was undertaken with the objective of identifying, measuring and comparing costs and benefits associated with BMP adoption.

In order to evaluate the financial implications of adoption, several analytical steps were required. The first step was the development of cost of production budgets for each one of the three crops at the respective research site. These budgets provided the basis for calculating the net margin for each enterprise for the baseline scenario. This is the scenario without the BMP adoption, or the one containing the status quo practice of the farmer before the adoption of the BMP. At this stage, the cost of investment associated with the baseline technology or practice was calculated.

The second step involved the identification and quantification of capital costs of investment related to the BMP. Furthermore, costs and benefits associated with the adoption of the BMP were then quantified and provided the basis for construction of the alternative scenario, also called the BMP scenario.

The third step consisted in establishing the duration of each project, projecting costs and benefits during the life of the project. At this stage the partial budgets of the farms, costs and benefits of other commodities – corn seed and wheat, lettuce, were also included in the analysis since they were grown in rotation with tomato and dry onions respectively.

The final steps of the analysis involved the incorporation of all these measurements into the calculation of the Net Present Value (NPV) of benefits. This was one of the criteria used for BMP appraisal, together with the Benefit-Cost Ratio (B/C). Sensitivity analysis was also conducted to observe the robustness of results related to commodity price changes and discount rate variations. In the following section each one of the concepts mentioned above are described in further details.

4.5.1.1 Investment Characteristics

The initial cost of investment involves long-term costs associated with the adoption of the new technology, which is an essential component in determining the profitability of a given BMP. For each of the sites, a distinct system cost was estimated either with the support of growers or equipment contractors. The initial costs of the systems included cost of material -- headers, connectors, valves, water pump, water reservoir, installation costs, and other costs associated with the BMP adoption such as a Global Positioning System (GPS) unit in Leamington. In Saint-Louis-de-Blandford, investment costs included drainage system changes and cost of tensiometers, whereas in Saint-Patrice-de-Sherrington the initial costs were associated with the sprinkler irrigation system, such as main and lateral pipelines, sprinkler heads and water pump.

For each one of the investments assumptions were made regarding the length of project. In each case, the useful life of the BMP was used as the duration of the investment. The useful life of the BMPs was established based on the information received from producers, irrigation equipment contractors and other studies. Subsurface drip irrigation has been studied in Canada, in Ontario, in a corn-producing farm. In this research, the useful life of this BMP was assumed to be 15 years (Jacques, 2014). Camp and Lamm (2003) mention that the expected life of this technology to range between 10 and 20 years. For this study, the subsurface drip irrigation system had a useful life of 15 years was assumed. At the end of this period, it was assumed that the system had no other economic value beyond its salvage value. This value was assumed to be equal to 35% of the initial capital cost of the irrigation pump and engine, the water reservoir and the GPS unit. It was assumed that the producer financed 75% of the investment through a loan. The duration of the loan was assumed to be 10 years and the average interest rate assumed was 4.75%, the average prime interest lending rate (AAFC, 2015).

In the cranberry case study, the BMP consisted of switching to a relatively dry water management practice. For this to be possible, in our case study farm, land improvements had to be made, which involved the reshaping of the drainage system. A sprinkler irrigation system was used for irrigation and tensiometers for triggering the irrigation. Given that the most substantial change required for this BMP was the land improvement, the life of this project to be 20 years was assumed, and no residual salvage value was assumed at the end of this period.

For the third case study, sprinkler irrigation was the studied BMP. It was assumed that the length of this project was of 15 years. The salvage value was calculated as 35% of the initial cost of the irrigation pump, water reservoir and aluminum sprinkler heads.

4.5.1.2 Baseline Scenarios

The first step in conducting the farm level analysis, involved the development of costs of production for each of the studied crops and technologies or practices. The baseline scenario represented each case study farm using the older practice or technology, reflective of water management systems currently used by other regional producers as well. For the Leamington case study, the net margin calculations for this scenario were made using the surface drip irrigation system. In the case of the cranberry farm in Saint-Louis-de-Blandford, the sprinkler irrigation system, with no control of the water table, was used to calculate net benefits. Lastly, for Saint-Patrice-de-Sherrington, a no irrigation practice was used to develop the baseline scenario.

A marginal analysis is a simple method of evaluating the profitability of an enterprise and it is calculated based on a partial budget of the farm. In this study, it was used to compare enterprises under different baseline and BMP technologies. The net income (NI) for each enterprise was calculated by subtracting all variable costs (VC) and fixed costs (FC) from gross income (GI), as shown in equation (4.1). A partial budget analysis represents a justified approach to conducting the financial analysis, in cases where the effects of the adopted BMP do not affect the entire farm. For our case studies, the farmers used the BMPs predominantly on the enterprises of interest – tomatoes, cranberries and onions. Next, income and costs for these three commodities are described in details:

$$NI = GI - VC - FC \tag{4.1}$$

Gross income data for tomato and cranberry production were obtained through interviews with agricultural producers. Prices and yields used to calculate the gross income were obtained from processors for the study year. For onion production, the figures were provided in part by the farm manager; however, most data used for this calculation were adapted from CRAAQ (2008). Variable costs included land preparation costs (i.e., plowing, bed shaping), cultural costs (i.e., pesticide and fertilizer applications), irrigation costs (i.e., start-up of the system, maintenance) and harvesting costs (i.e., harvester use, labor). Producers for tomato and cranberry production provided these costs. For onion production, available costs of production were used from CRAAQ (2008).

4.5.1.3 BMP Scenarios

The alternative scenarios were developed by considering changes brought forward by the adoption of the BMP. For each site, an alternative scenario was developed. In Leamington, gross margins of tomato production under a subsurface drip irrigation system constituted the alternative scenario. Subsurface drip irrigation is a low-pressure, low-volume system, with drip tubes placed below the soil surface at a depth of approximately 15-20 cm (depending on soil type, crop and tillage practices).

The producer provided most changes in the cost of production for the tomato enterprise. There was no difference in yield between tomatoes grown under a baseline scenario, or a BMP scenario. While there was a decrease in annual operating cost under the BMP scenario, there were also some additional costs associated with this alternative, such as more specialized machinery needed for installation, and increased managerial decision-making time, among others. Tomatoes costs of production under a baseline and BMP scenario are described in detail in the next chapter, in Section 5.2.1.

In Saint-Louis-de-Blandford, the alternative scenario involved cranberry production under sub-irrigation. As noted above, this BMP is a dual-purpose water management system that provides both irrigation and drainage. Additional water can be supplied through the same pipes that are used for drainage. The water table depth is regulated with the use of control structures. In order to maintain an appropriate water table depth, water is supplied under the surface to provide ideal moisture conditions in the effective root-zone (Handyside, 2003).

The gross margin calculations for cranberry production, under the alternative scenario, reflected changes brought forward by the adoption of subirrigation. The benefits created by this scenario included: increased yields, reduction of water use and energy use. Some of the costs associated with this BMP were due to increased managerial decision-making.

In Saint-Patrice-de-Sherrington, the alternative scenario involved onion production under sprinkler irrigation with the use of tensiometers for triggering irrigation. Tensiometers are soil moisture monitoring devices that can be either buried in the ground or portable (Short et al., 2011). The Hortau tensiometer was used for this site. It is a “bury in place” device. Soil water potentials were measured using wireless electronic tensiometers (TX-80-WL and TX3, Hortau Inc.) inserted at a depth of 0.2 and 0.3m (Rekika et al., 2014). The major benefits from this BMP included a substantial increase in onion yields. In addition to benefits, the BMP had certain increased costs, such as increase for labour time needed together with and increased managerial decision-making time.

4.5.1.4 Investment Appraisal Criteria

Evaluating a BMP’s profitability over its lifespan is essential for agricultural producers as it represents a key information needed in their adoption decision-making process. The financial viability of an agricultural project is typically ascertained by analyzing net cash inflows and outflows over the investment’s planned life (Sell, 1991). The main purpose of comparing costs and benefits of the investment is to help the producer decide which projects are worth adopting, and which ones to reject. There are two measures used to evaluate an investment’s worth: Benefit/Cost Ratio (BCR) and Net Present Value (NPV). Estimation of each of these requires several steps.

Both measures noted above require discounted values of benefits and costs. Selecting a discount rate for the financial analysis is a critical step in evaluating an investment’s worth, as it can have a large impact on analysis results (Olson, 2011). Discounting future income streams accounts for consideration of risks associated with the investment. The cost can be estimated using equation (4.2), where i_a is the weighted average cost of capital, i_d is the interest rate on debt, t denotes the income tax rate, D/A is the debt to asset ratio (i.e., is the cost of equity capital), and

E/A is the equity to asset ratio. The cost of equity, also referred to equity opportunity cost, is the highest rate of return that could be earned by investing in another option with similar risk (Olson, 2011).

$$i_a = i_d(1-t)\left(\frac{D}{A}\right) + i_e\left(\frac{E}{A}\right) \quad (4.2)$$

The Net Present Value (NPV) is the most commonly used appraisal criterion for investment projects. It is calculated by subtracting all periodic discounted outflows from the discounted inflows of a project over the life of the investment. In other words, the NPV of a project is the difference between the present value of benefits and costs, as shown in equation (4.3), where B_t represents project revenues in period *t*, C_t are project costs in period t, i is the selected discount rate and *T* is the number of years denoting the planning horizon for the project (Boardman et al., 2001).

To account for the time value of money, a discount rate of 5% was used for the farm financial analysis, while higher discount rates of 10% and 15% were used in sensitivity analyses. Trautman et al. (2012) used 10% for their evaluation of private costs and benefits of BMP adoption, whereas Seens (2015) uses a 5% discount rate. While consensus lacks in terms of the appropriate discount rate, for this study the decision was to use a moderately conservative rate for the financial analyses and use higher discount rates for sensitivity analyses.

For the evaluation of the three BMPs analyzed in this study, the NPV was used as one of the appraisal criteria. The BMP with the highest NPV is typically the preferred options. However, the simple decision rule is to accept projects with a positive NPV (Brown, 1980).

$$NPV = \sum_{t=0}^{T} \frac{B_t}{(1+i)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \quad (4.3)$$

Benefit-Cost Ratio (BCR) represents another appraisal criterion, which indicates whether a project would add to the economic wellbeing of the individual or society. It is calculated by dividing the sum of discounted benefits by the total discounted costs, as shown in equation (4.4). A BCR of over one suggests that the overall benefits outweigh the costs and the BMP is deemed acceptable. However, if the BCR's value is close to one, then consideration of other reasons for accepting the BMP is required. Furthermore, the BCR can also be used to rank options.

$$BCR = \sum_{t=0}^{T} \frac{B_t}{(1+i)^t} \Big/ \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \tag{4.4}$$

4.5.1.5 Sensitivity Analysis

Sensitivity analysis is a set of techniques, used to evaluate the robustness of analysis outcome. It is considered a critical component of appraisal methodology for an investment (Fiacco, 1983). Models, such as farm or enterprise budgets, are developed using assumptions and parameters, which can be erroneous or have changing values over time. These changes can have a significant impact on the results provided by an appraisal. Sensitivity analysis investigates potential changes and their impact on the analysis outcome (Pannell, 1997). This analysis evaluates the range of changes in outcomes (measures used for appraisal) given changes in the value of economic assumptions.

In this study, it was hypothesized that the economic desirability of a BMP would be associated with variations in several factors, including commodity prices, commodity yield, area cultivated, and precipitation levels. Commodity prices were selected due to the tendency of this factor to fluctuate over time. Another factor of interest is the yield, which is affected both by climatic conditions, and by managerial responses and decisions associated with these changes. Area cultivated could be a relevant factor to ascertain if the investment in the BMP is scale dependent. Another important factor in sensitivity analyses relates to the level of precipitation. This provides an understanding of the performance of the BMPs under different climatic regimes. To evaluate the robustness of NPV calculations and to provide recommendations based on these results.

4.5.2. Modelling Decision Adoption

Knowledge of the factors influencing agricultural producers' decisions regarding adoption of improved management practices can be important for policy purposes. Alternative policy instruments can be compared as to their efficacy in incentivizing adoption of a BMP. This is typically based on prediction of the likelihood that adoption of particular innovations will take place under the selected policy instrument.

Throughout the social sciences, research related to binary choices is abundant in the fields of economics, sociology, policy, and many others. That is because many of the choices humans are faced with are "either/or" in nature (Hill et al., 2008). Typical examples include whether to purchase a commodity, whether to irrigate or not to irrigate, or to vote or not to vote, etc.

The agricultural producer faces a similar choice, when deciding whether to adopt an improved practice or technology for his or her farm. As reviewed in Chapter 3, the decision process is influenced by the attributes of the decision-maker, the decision object, socio-economic context, and so forth. Knowledge of which factors contribute to the decision can be helpful in developing appropriate policies.

Binary choice models are statistical models used to estimate the value of a response variable with a change in some stimulus variables. In these models, the assumption is that the choice of the decision-maker is bounded by two choices, mutually exclusive, which are coded with 1 or 0 -- adoption of a new practice or non-adoption, respectively. Binary choice models are used to estimate the probabilities associated with these options and the relationship of the dependent variable and a set of predictors or independent variables.

4.5.2.1 Selection of the Model

<u>Logistic Regression Model for Modelling Adoption</u>: There are several statistical techniques used to model discrete outcomes. Among the commonly used ones are linear, probit and logit regression models. Within the agricultural adoption literature, the most commonly used model is the logistic regression. The following section describes these models and their caveats, together with the arguments for the selection of the logistic model for the analysis.

The binary discrete choice regression models are described using the two possible outcomes. Variable Y is defined, and it can assume two values:

$$Y = \begin{cases} 1 & \text{decision} - \text{maker chooses to } \textit{adopt} \text{ the BMP} \\ 0 & \text{decision} - \text{maker chooses to } \textit{not adopt} \text{ the BMP} \end{cases}$$

The linear probability model is represented by a simple linear function, as shown in equation (4.5). Here the value of the dependent variable (0 or 1) is regressed against several selected independent variables.

$$Y_i = \beta_0 + \beta_1 X_{i1} + \cdots + \beta_p X_{ip} + \varepsilon_i \tag{4.5}$$

Where, Y_i is the response or independent variable for observations i = 1, ..., n; β is a parameter vector, containing regression coefficients β_0 to β_p, indicating the quantified relation between explanatory variables and Y_i; X is a vector of explanatory variables, X_{i1} to X_{ip}, each measured on the i^{th} observation, and ε_i represents the error term for i = 1, …, n independent and normally distributed terms with mean 0 and variance s^2_{ε}.

The results of a linear regression model are straightforward to interpret and easy to communicate. However, there is wide agreement that its application for dichotomous response variables raises several issues. Nonsensical predictions are one of the issues related to using linear regression for binary response variables (Bilder and Loughin, 2014). This means that predicted values with this linear model could be outside the probability boundaries of 0 and 1.

Another issue frequently mentioned in the context of the linear probability models is heteroskedasticity. This means that the variance of error terms is not constant, which results in inefficient estimators. Furthermore, the standard errors of estimates are biased (Hill et al., 2008). Hellevik (2009) provides a counter point to this issue, mentioning that there is little practical importance related to the violation of the homoscedastic errors assumption. The same author notes that when selecting a statistical technique, the purpose of conducting the analysis will have an important role to play in the decision. While linear regressions are used in causal or path analysis, the logistic regression model is generally used for prediction analysis of outcomes.

The probit model allows for the values of the choice probability to be bounded by 0 and 1, as lower and upper limits, accounting for one of the linear regression model limitations. The probit function is related to the standard normal distribution of the probability and it is modeled as a linear combination of the predictors. The maximum likelihood technique is used for estimation of its parameters, as opposed to the least square method used with the linear model. The probit (and the logit) model has a nonlinear S-shaped curve that defines the relationship between an explanatory variable and choice probability (Hill et al., 2008).

The logit model, also known as the binary logistic regression model, is very similar to the probit model. These statistical techniques are designed for modelling the probability of an event that is binary. The logit is used widely in the literature to model farmers' adoption decisions. Compared to the linear model it has the advantage of bounding probability of occurrence between 0 and 1. One of the main theoretical differences between the probit and the logit resides in the difference in the probability density functions underlying them. The probit model has a standard normal cumulative distribution function, whereas the logit model is based on a logistic cumulative distribution function. Both functions have similar S-shaped curves, with the logistic distribution being more spread out at the tails (Hill et al., 2008; Bilder and Loughin, 2014).

In selecting one model over the other, Chen and Tsurumi (2010) propose several estimators of model quality, to differentiate between models (i.e., Akaike information criterion). These criteria discriminate between models, and help select the better one, in cases where the dependent variable is unbalanced – does not have an equal split of cases into the two levels or categories. In cases, where this equal split exists, either one of the models can be equally used. In this study, the logistic regression model was used to explain adoption, due to its wide use in this area of research. Kennedy (2008, pg. 242) mentions that historical proclivities for using a logit model, were related to ease of estimation – less computationally intensive.

Logistic regression models are categorized as generalized linear models (GLMs). They consist of a random component, Y which has a Bernoulli distribution, a systematic component, the linear predictor Z_i of p explanatory variables, as defined in Equation 4.7, and a link function – which specifies the link between the expected value of the random component E(Y) and the linear predictor (Bilder and Loughin, 2014). In the logit model, the probability P_i that Y=1 usually takes the form shown in equation (4.6):

$$P_i = \frac{e^{z_i}}{1+e^{z_i}} \qquad (4.6)$$

$$Z_i = \beta_0 + \beta_1 X_{i1} + \cdots + \beta_p X_{ip} \qquad (4.7)$$

A regression model can also be written using equation (4.8):

$$\ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_{i1} + \cdots + \beta_p X_{ip} + \varepsilon_i = \text{logit}(P_i) = \ln odds \qquad (4.8)$$

Here, P_i is the probability that the i^{th} observation has an outcome Y_i is 1, conversely 1-P_i is the probability that Y_i is 0. The *odds* are the ratio of P_i and 1-P_i. By taking the natural logarithm of the *odds* ratio (*ln odds*), the linear prediction equation is obtained.

Estimation of the binary logistic regression model is realized using a Maximum Likelihood Estimation (MLE) technique. The MLE method seeks to find those values of parameters for which the log-likelihood function is maximized (Hill et al., 2008). The log-likelihood function, used to estimate parameters $\beta_0, \beta_1, \ldots, \beta_p$, for a response variable Y_i, is expressed in equation 4.9 where π_i represents probability and Π denotes product.

$$\log\left[L\left(\beta_0, \beta_1, \ldots, \beta_p \middle| y_1, \ldots, y_n\right)\right] = \log\left(\prod_{i=1}^{n} \pi_i^{y_i} (1 - \pi_i)^{1-y_i}\right) \tag{4.9}$$

In this study, the logistic regression model was selected for modelling adoption decisions. While there are no major distinctions between a probit and a logit model, in this study, the logistic regression was used to build the study model, because it has been the standard in the area of farmers' decision adoption modelling.

Ordered Logistic Regression Model for Modelling Perception: The logistic regression model is used when the outcome variable is dichotomous or has two levels – as is the case with modelling adoption decisions, where the response variable is conceptualized as a binary variable - yes or no. Whenever the response variable has more than two possible choices, multinomial logit or probit regressions are used to relate the dependent and independent variables (Hosmer et al., 2013). However, multinomial models are used only when outcome variables are measured on nominal scales. Whenever choice alternatives represent ordinal categories, ordered choice models are required (Hill et al., 2008). For example, in this study, assessment of factors influencing farmers' perception of a BMP's relative advantage was measured initially using a five level Likert scale -- strongly disagree, disagree, neutral, agree, or strongly agree. This variable was later recoded into three levels – level one included both levels of disagreement, level two contained only the neutral responses, and level three contained the level of agreement. Collapsing categories helps eliminate cases with zero or a small number of observations. In relation to effect on estimation accuracy – false positive or Type I error, Murad et al. (2003) showed that the practice of collapsing adjacent categories does not influence the proportion of Type I errors – false positives (a condition is found to be present when in reality it is not).

$$y = \begin{cases} 1 & strongly\ disagree, disagree \\ 2 & neutral \\ 3 & agree, strongly\ agree \end{cases}$$

McKelvey and Zavoina (1975) demonstrate the limitations of using linear regressions when the dependent variable is ordinal. More precisely, the authors show that due to the ordinal scale of the response variable, the usual assumptions, associated with conventional regression models, do not hold, as well as the non-linear relationship between the variables is not appropriately accounted for. Another issue is related to the fact that in a regression model, the values of estimated coefficients depend on the values attributed to the categories of the response variable. However, this is problematic in the case of ordinal variables, where the numerical labelling of categories is arbitrary. Using an extension of the binary probit model, in this study an alternative that is more appropriate for analyzing ordinal variables, was used. This model is called an ordered probit or a logit model.

Ordered choice models, like binary choice models, are grouped into two categories: probit and logit models. In the ordered probit model, errors follow a normal distribution, whereas in an ordered logit model, the errors are assumed to follow a logistic distribution (Hill et al., 2008). As in the case of binary choice models, there are only small differences between the ordered logit and the probit models. Hill et al., (2008) note that these differences are inconsequential to the obtained results. In this study, an ordered logit model was used to analyze the effects of factors on farmers' perception of the relative advantage of a BMP.

In the ordered logit model, y -- the ordinal dependent variable, is perceived as an unobservable random variable, also referred to as latent variable and denoted by y*. The unobservable response variable can be related to explanatory variables, through the index model, shown in equation (4.10). The vector of regression coefficients is denoted by β, x is the explanatory variables vector, and ε is the error term.

$$y_i^* = \beta x_i + \varepsilon_i \tag{4.10}$$

Assuming that there are three choices available for the response variable, there will be two thresholds ($\alpha_1 and\ \alpha_2$) – also called cutoff points or category boundary. There are no intercepts in index models, because they would be collinear with $\alpha_1 and\ \alpha_2$. The model can be rewritten as shown in equation (4.11).

$$y = \begin{cases} 1 \quad strongly\ disagree, disagree & if \quad y^* \leq \alpha_1 \\ 2 \quad neutral & if \quad \alpha_1 < y^* \leq \alpha_2 \\ 3 \quad agree, strongly\ agree & if \quad y^* > \alpha_2 \end{cases}$$

(4.11)

The assumption that the error term in the index model y* follows a logistic distribution defines the ordered logit model. There are three different types of ordered logit model, in which the categories of the dependent variable are treated differently. Hosmer et al. (2013) note that three of the most commonly used models are the adjacent-category, the continuation-ratio and the proportional odds models. Fullerton (2009) provides a typology of ordered logit models and divides them based on the approach to comparisons (cumulative, stage, and adjacent) and the application of the proportional odds assumption (to all, some, or no independent variables).

The cumulative approach developed initially to be used for outcome variables was in an ordinal scale that represents an underlying continuous measure (for example a variable measured on a Likert scale (Fullerton, 2009)). The cumulative approach compares probability of an equal or smaller response (Hosmer et al., 2013). Developed by McCullagh (1980), the proportional odds model is the most frequently used ordered logit model and it is the most common cumulative approach (Fullerton, 2009). It was developed with the scope of being used for ordinal variables and to address the issue of assigning values arbitrarily to variables. It assumes that the cut-off points between variables are not known (Fullerton, 2009). Equation (4.12) specifies the proportional odds model, where j is the category, x is a vector containing the independent variables, α is the cut-off point and $\beta$is a coefficients vector.

$$Log\left(\frac{\Pr(y \leq \alpha|x}{\Pr(y > \alpha|x}\right) = \alpha_j - x\beta \qquad 1 \leq j < J$$

(4.12)

Then the probability for any given outcome category (J) in the proportional odds model can be specified as shown in equation (4.13), with F denoting the logistic cumulative density function.

$$\Pr(y = j|x) = \begin{cases} F\left(\alpha_1 - x\beta\right) & j = 1 \\ F\left(\alpha_j - x\beta\right) - F\left(\alpha_{j-1} - x\beta\right) & 1 < j \leq J - 1 \\ 1 - F\left(\alpha_{J-1} - x\beta\right) & j = J \end{cases} \tag{4.13}$$

For modelling perceptions of the BMP, the most common ordinal logistic regression model was used, which is the cumulative odds ordinal logistic regression with proportional odds.

4.5.2.2 Association between Variables

Understanding the level of association between two variables, such as farmer's characteristics being instrumental in a BMP, can provide additional insight into agricultural producers' decision-making process. The Chi-Square test of independence, also called Pearson's Chi-Squared, is a statistical technique used to determine if there is a significant association between two categorical variables. The null hypothesis underlying the test states that the two variables tested are independent or not related, whereas the alternative hypothesis assumes the opposite. The frequencies of the two variables can be presented in a contingency table of r rows and c columns. The Chi-Square test of independence, denoted by χ^2, is calculated using equation (4.14):

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{(O_{ij} - E_{ij})^2}{E_{ij}} \tag{4.14}$$

The O_{ij} denoted the observed frequencies for level *i* of the first variable, and level *j* of the second one. The E_{ij} represents the expected frequencies of the two variables. The degrees of freedom are calculated using the formula (r-1) x (c-1) (Miah, 2016). If the calculated value of Chi-Square is greater than the table value, the null hypothesis is rejected, yielding the conclusion that the two variables are associated. However, the Chi-Square test of independence does not provide information regarding the strength of the association between two variables.

4.5.2.3 Analytical Framework

In this study, building regression models was undertaken for two reasons. With the binary logistic model, one could attempt to explain what factors contribute to a farmer's decision to adopt or not a certain BMP, where adoption is measured as a binary variable. With the ordered logistic regression model, the objective is to explain what factors contribute to a farmer's perception that the proposed BMP is a better alternative than the practice they currently use, where perception is an ordered variable (strongly agree, agree, neutral, disagree, and strongly disagree).

The estimation of a regression model involves several steps. After the identification of the appropriate probability model, the next step in building the regression model is to select explanatory variables to be included in the model. Following this, the models prepared are compared against a set of criteria and the model that outperforms the rest is selected. The final steps of model building involve evaluation of the model's goodness of fit and robustness. The steps involved in building a regression model are described in the following sub-sections.

4.5.2.4 Selection of Variables

The preliminary selection of the explanatory variables was based on the Theory of Planned Behaviour and Diffusion of Innovations, attributed to researchers Ajzen (1991) and Rogers (2003), respectively. These theories provide support for understanding and explaining human behaviour related to decision-making. As noted in Chapter 3, these theories highlight several factors that are relevant in the context of agricultural producers' adoption decision-making. To better understand farmers' choices, empirical studies were also consulted, including those by Baumgart-Getz et al. (2012), Bjornlund et al. (2009), Greiner et al. (2009), Kulshreshtha and Brown (1993), Pannell et al. (2006), Prokopy et al. (2008), and Reimer et al. (2012). Variables considered for the binary logistic regression included factors related to farmers' characteristics (i.e., age, education, farming experience, etc.), and farmers' perceptions of the BMPs, and farm characteristics (i.e., crop type, sales from a crop, farm size, etc.). These factors are summarized in Table 4.4.

While the binary regression model was developed for understanding contribution of factors to farmers' decision to adopt BMPs, the ordered logit regression model was developed to identify factors important in farmers' perception of the BMP as an alternative to the practice or technology already/previously in use on their farms. Using Ajzen's Theory of Planned Behaviour and Roger's Diffusion of Innovation, along with works of Reimer et al. (2012), Pannell et al. (2006), Lynne et al. (1995), factors were selected for the ordered logit model. Table 4.5 summarizes information regarding the dependent and independent variables, included in the perception ordered logistic model.

After the initial selection of the explanatory variables, a stepwise forward selection technique was used to include them in the model. Stepwise search algorithms were used for variable selection for modelling both adoption decision and farmers' perceptions of BMPs. These algorithms could be based on a forward selection technique, which begins with a model containing no variables and one variable at a time is added, or a backward elimination technique that starts with a full model, after which variables are eliminated one at a time based on the value of the information criteria indicating that the model is improving. Bilder and Loughin (2014) explain in detail the steps involved in these techniques.

4.5.2.5 Interaction between Variables

When substantiated by theory, interaction terms can be introduced in the regression model if they result in an improved model. Some of the most common interaction terms are pairwise interactions. Interactions between two independent variables are needed when the effect of one variable on the probability of success depends on the value of another variable (Bilder and Loughin, 2014). In this study, interaction terms were included in the ordered logistic regression model, following procedures from Berry et al. (2010), which are similar to the inclusion or exclusion of other explanatory variables. The procedure includes: develop a hypothesis regarding the interaction term; determine whether the coefficient of the term is statistically significant; reject or accept hypothesis based on statistical significance of the coefficient.

4.5.2.6 Models estimation

To estimate both the logit and the ordered logit models, IBM's Statistical Software Package for Social Scientists (SPSS), version 25 was used. The binary logistic model was fitted using the Logistic Regression "entry" procedure. In this procedure, all predictors are introduced in the model at once, in one step. To estimate the ordinal logit regression model, the SPSS PLUM (Polytomous Universal Model) procedure was used, which is an extension of generalized linear models for ordinal dependent variable prediction. The PLUM procedure has several link functions, among which the logit function, used in this study to fit the proportional odds model.

Table 4.4. Description of Variables Considered for the Binary Logistic Model

Acronym	Description	Type of measure	Expected Sign
Dependent variable			
ADOPT	Distinguishes between adopters and non-adopters	Categorical 1 = yes 0 = no	
Explanatory variables			
AGE	Farmer's age group	1 = under 35 years 2 = between 35-55 3 = over 55 years	-
EDUC	Farmer's level of education	1 = High school 2 = College/Technical Degree 3 = University or Professional Degree	+
EXP	Years of farming experience	Continuous, numeric	-
OWN	Percentage of land owned	Continuous, numeric	+
ORG	Membership in agricultural organizations	Continuous, numeric	+
BMP	Previous adoption of BMPs	1 = yes 0 = no	+
GOALS	Farming related goals	0 = exclusively economic 1 = economic and non-economic	+
CROP	Type of crop related to the BMP adoption	1=Tomatoes 2=Cranberries 3=Onions	?
INOME	Percentage of the grower's income coming from farming	Continuous, Numeric	+
FSIZE	Farm size in acres	Continuous, Numeric	+
CROSIZE	The acres allocated to the crop related to the BMP adoption	Continuous, Numeric	-
SALES	Farm's sale levels	1= Less than $50,000 2= $50,000-$99,000 3= $100,000-$249,000 4= $250,000-$499,999 5= $500,000-$1,000,000 6= More than $1,000,000	+
CROSALE	Percentage of sales corresponding to the crop of interest	Continuous, Numeric	+

Table 4.5. Description of Variables Considered for the Ordered Logistic Model

Acronym	**Description**	**Type of measure**	**Expected Sign**
Dependent variable			
BETTER	Agreement level with the statement: in the context of your farm the BMP could be a better alternative than the current one	Categorical, ordered -1= Strongly Disagree, Disagree 0 = Neutral 1 = Agree, Strongly Agree	
Explanatory variables			
AGE	Farmer's age group	1 = under 35 years 2 = between 35-55 3 = over 55 years	-
EDUC	Farmer's level of education	1 = High school 2 = College/Technical Degree 3 = University or Professional Degree	+
EXP	Years of farming experience	Continuous, numeric	-
OWN	Percentage of land owned	Continuous, numeric	+
ORG	Membership in agricultural organizations	Continuous, numeric	+
BMP	Previous adoption of BMPs	1 = yes 0 = no	+
GOALS	Farming related goals	0 = exclusively economic 1 = economic and non-economic	+
CROP	Type of crop related to the BMP adoption	1=Tomatoes 2=Cranberries 3=Onions	?
INOME	Percentage of the grower's income coming from farming	Continuous, Numeric	+
FSIZE	Farm size in acres	Continuous, Numeric	+
CROSIZE	The acres allocated to the crop related to the BMP adoption	Continuous, Numeric	-
SALES	Farm's sale levels	1= Less than $50,000 2= $50,000-$99,000 3= $100,000-$249,000 4= $250,000-$499,999 5= $500,000-$1,000,000 6= More than $1,000,000	+

CROSALE	Percentage of sales corresponding to the crop of interest	Continuous, Numeric	+
BPROF	Agreement level with the statement: in the context of your farm the BMP could be profitable	Scale 1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree	+
BEXP	Agreement level with the statement: in the context of your farm the BMP could be expensive	Scale 1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree	−
BESTUSE	Agreement level with the statement: making best use of scarce resources is important t	Scale 1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree	+
WATERUSE	Agreement level with the statement: reducing water use in agriculture is important	Scale 1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree	+

4.5.2.7 Comparing Models

Comparison of estimated models is an important step in model building. This comparison supports the identification of additional information regarding the quality of the constructed model. Information criteria measures, such as the Akaike's Information Criterion (AIC), and Bayesian Information Criterion (BIC), give preference to parsimonious models. These criteria allow for comparison of non-nested models and include a penalty for each variable included in the model. When assessing two models, AIC and BIC are both important, each showing a slightly different effect. In this context AIC shows efficiency, while BIC reveals consistency. Generally, a model with a lower IC is preferred over one with a larger score (Bilder and Loughin, 2014). In this study AIC and BIC criteria were used for model comparison.

4.5.2.8 Model Evaluation

Assessing the goodness-of-fit of a model is an important step in building a regression model. Several tests can be used to assess the overall fit or the correctness of specification of a logistic regression model. One of the most commonly used goodness-of-fit tests is Hosmer-Lemeshow GOF. The GOF test's outcome is a p-value. If the p-value is lower than 0.05, the model is rejected. However, Bilder and Loughin (2014) mention that there is a distinction between a fitting model and a good model. Due to the volatility of the Hosmer-Lemeshow GOF, King (2008) suggests using alternative measures to assess the GOF, such as AIC and BIC.

In addition to goodness-of-fit, models are also evaluated based on their capability of outcome prediction. While there is no equivalent R^2 for logistic regressions, there are still varieties of statistics that are similar, which are usually reported. One of the most commonly reported R^2 values for logistic regressions is McFadden's pseudo R^2. However, there is no consensus as to which one of the R^2 measures should be preferred. Some authors discourage their reporting altogether, because they are not considered good measures of outcome prediction (King, 2008).

Classification-based approaches are a different way to assess fit of models. They indicate how accurate the model is at correctly separating cases into the two groups based on the occurrence of the event (Esarey and Pierce, 2012). The weakness of this approach[17] is that it does not provide information regarding the model's power to predict; it only indicates the accuracy of the model to separate the cases. There are different other indicators provided by various statistical packages to improve on the limitations of the classification table. Adjusted count R^2 indicates the proportion of correct predictions, beyond the number that would be correctly guessed by choosing the most frequent outcome. Another commonly used method of observing the sensitivity and the specificity of a model is by using the Receiver Operating Characteristic Curve (ROC) with the Area Under the Curve (AUC) measurement.

4.5.2.9 Robustness of the Model

Collinearity is present within a regression model if a linear relation exists between predictors. Its presence does not hinder the model's prediction capability; however, it might

[17] An extended discussion on the limitations of this approach are provided by King (2008 p.375), and Esarey and Pierce (2012).

produce unreliable coefficients and inflated standard errors (King, 2008, p. 379). In order to correct for this issue, several approaches can be used. While some authors suggest centering the variable responsible for collinearity problems (UCLA, 2016), others advise against that approach and suggest the removal of the variable from the model (King, 2008). Two indicators used to measure the strength of the relationship between predictors are tolerance, and variance inflation factor (vif). Tolerance indicates the extent to which the regression analysis can accept the collinearity. The vif indicator is calculated based on the tolerance and it measures the extent to which the inflation in the standard error is attributed to collinearity (UCLA, 2016).

Model robustness can also be perturbed by influential cases. These are observations that can be outliers or significantly influence the results of the regression model. There are several indicators generally used to identify these effects; among which the most common are standard Pearson residuals, deviance, Pregibon leverage or Pregibon's Delta-Beta similar, and Cook's distance (King, 2008). Pearson residuals represent the difference between observed and predicted values. Hence, a case with a large residual value can be an outlier as the model predicts its value poorly. It is indicated that instead of simply discarding these cases, they should be revised to make sure there are no errors introduced during the coding of variables. Pregibon's leverage and Cookk's distance were used in this study to assess the presence of influential observations.

Outliers can be symptomatic of other issues as well; they could be an indication that key variables are missing from the model. Standardized residual plots are good means of exploring the dispersion of the difference between observed and predicted values using the created model. Pearson's standardized residuals should lie between -2 and +2 and according to Bilder and Loughin (2014, p.289), with only 5% of values lying beyond this range and none beyond ±3. In this study, Pearson's standardized residuals were used to investigate outliers.

4.6 SUMMARY

This chapter begins by providing an overview of the research approach and the three research sites located in Ontario and Québec – Leamington, Saint-Louis-de-Blandford and Saint-Patrice-de-Sherrington. Following this, the data collection process is described, starting with questionnaire development, sampling design, and sample characteristics. The last section of the chapter contains the description of methods of analysis. The main method of analysis for evaluating the financial viability of BMP adoption is done using marginal analysis. It is this method that is described in the first part of the last section, followed by a description of regression model building and evaluation. Regression models were the techniques used to identify important determinants of adoption and of BMP perception.

CHAPTER 5. FARM LEVEL ANALYSIS RESULTS AND DISCUSSION

5.1 INTRODUCTION

This chapter contains farm analyses results for each one of the three case studies. For each case study the characteristics of the farm and enterprise are presented, followed by capital costs associated with the water management practice or technology currently in use (baseline scenario), and the proposed alternative (BMP scenario). Next, the effect of the BMP on the enterprise revenues and costs is described, after which non-financial changes associated with the adoption of the BMP – social and environmental effects are described. Using NPV and BCR as appraisal criteria for these investments, the two scenarios are compared. The last step in each analysis consists of checking the sensitivity of profitability indicators, to variations in key parameters – crop price changes, yield, farm area, etc.

5.2 ON-FARM EVALUATION OF BMPs

This section contains results of financial evaluation of the three BMPs on the case study farms. Results of the profitability of producing tomatoes, cranberries and onions under a baseline scenario are presented first in Subsection 5.2.1 to 5.2.3. This is followed by results for the profitability of growing these commodities using the selected BMP. A comparison of profitability under the two scenario is reported next, followed by results of sensitivity analyses for each BMP. The latter included effects of varying crop yields, prices and area under the crop on the profitability of growing fruits and vegetables under the selected BMP.

5.2.1 Financial Analysis of BMP for Tomato Production

The first case study focused on the financial analysis of investing in subsurface drip irrigation on a 400 ha (1,000 acres) farm growing tomatoes located in Leamington, Southern Ontario. On this farm, approximately 10% of the total area is dedicated to tomato cultivation. The grower uses both surface and subsurface drip irrigation as water management systems. Tomatoes are grown in a two-year crop rotation, where the producer alternates between seed corn and wheat.

Tomatoes are grown on raised beds, with the following dimensions 1.5m x 8m (5 feet by 26 feet). The farm section dedicated to tomato production has sandy loam soil, and the terrain varies from flat to undulating. Water sources for irrigation are mixed, with water coming from an on-farm reservoir, filled by precipitations or from the municipal ditch, and from Lake Erie, through a private irrigation project called LADII (Leamington Area Drip Irrigation Incorporation). The producers' water cost through LADII is approximately 20$/acre/inch, and the cost of fixed ownership of LADII pipeline 300$/year/acre.

The surveyed producer installed the surface drip irrigation system (baseline technology) on half of his tomato production area and a subsurface drip irrigation (study BMP) system on the other half. There were two factors, which contributed to this decision:

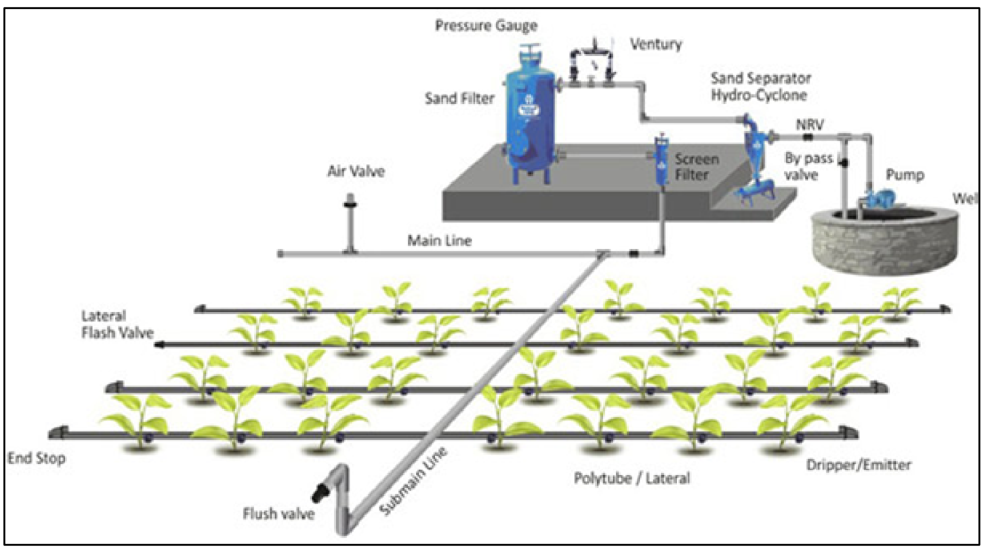
1. Spatial variability of the terrain – the surface drip irrigation system was installed in areas with undulating terrain, whereas the subsurface drip irrigation system in areas where the terrain was flatter;
2. Texture of the soil – the grower determined that it was more likely to have improved effects if the sub-surface drip system is installed on sandier soils as opposed to loamier ones.

The grower adopted the subsurface drip irrigation system gradually and several configurations of the system were tried, before the optimal set-up was found. The new irrigation system was tried first on 1-5 acres over a period of 4 years. Once a reliable water supply was in place (through the LADII project), it was extended to 50 acres. In the first year of subsurface drip irrigation installation, the yields diminished slightly in comparison to the year prior to installation. It was because the subsurface irrigation system was installed too deep into the ground (23 cm or 9-inch initial installation). In the second year, the system was reinstalled at a depth of 15 cm (6 inches). This led to yield increase in the subsequent year. While initially the system was left in the soil for 7 years, this proved inefficient because of high maintenance costs. After the trial period, the system was left in the soil for an optimum period of 3 years

The surface drip irrigation system (baseline technology) is installed every year in June and taken out in August, whereas the subsurface drip irrigation is installed in early April and removed every three years after harvest. In the case of the surface drip irrigation system, the tomato plant must be well established before the irrigation system is placed in the field. This ensures that the risks of damaging the plants are minimized. During installation and throughout the growing season, the surface drip irrigation could be affected by heavy winds, as well as damaged by mice, dogs, deer or accidentally by workers. There are fewer challenges with the installation of the subsurface drip irrigation system, as this is done early in the year, before the tomato transplants have been planted. While the subsurface drip irrigation system does not suffer as many external damages throughout the growing season, it still requires constant checks to ensure that the buried tapes are not clogged or torn.

There are some differences related to the drip tape used for the two systems. For the surface drip system, the tape used is the thinner model (4 mm), which costs \$185 per acre, whereas for the subsurface system a thicker model of tape is installed (6 – 8 mm), at a higher cost of \$234 per acre. The cost of installing the tape for both systems is similar; on average labor requirements amount to approximately 2 hours per acre for two people. When including machinery usage and fuel (80 hp tractor), the total tape installation cost adds to \$254 per acre to the total cost of installing the BMP – cost incurred every three years.

The subsurface drip irrigation system comprises several pieces of equipment and materials. Figure 5.1 shows the layout and components of a typical subsurface drip irrigation system. The soil depth at which the tape is installed, depends on soil type, tillage practices and crop grown, the low-pressure system is usually installed at a depth of 15 – 20 cm.



Source: GokulPlast (2018)

Figure 5.1. Layout and Components of a Typical Subsurface Irrigation System

The cost of investment of surface and subsurface drip irrigation systems are similar, in terms of system materials (i.e., mainlines, pipelines, etc.) and installation costs (Table 5.1). However, the main difference between the two systems invloves the purchase of a GPS unit, needed to accurately install a subsurface drip irrigation system. The cost of investment data were provided by the producer but supplemented with those aquired through personal communication with Nissim Maman from Aquadrip Inc.

Table 5.1. Cost of Investment for Baseline and BMP Technology for Tomato Production ($/acre)

Items		**Baseline (Surface Drip)**	**BMP (Subsurface Drip)**
System Materials			
	Mainline (PVC Pipe 4"/10 cm)	$140.14	$140.14
	Lateral Line (Header 3"/7.5 cm)	$112.11	$112.11
	Drip Line (4mm, Streamline Netafim)	$184.98	$233.56
	Connectors	$30.83	$46.71
	Manual Valves and Fittings	$28.03	$28.03
	Automatic Valves and Fittings	$18.68	$18.68
	Irrigation Pump (500 gal/min)	$46.71	$46.71
	Irrigation Engine (100hp)	$186.85	$186.85
	Filter Station	$46.71	$46.71
	Pressure regulators	$14.01	$14.01
	Water meter	$3.74	$3.74
	Fertilizer injectors	$2.80	$2.80
Installation			
	Labor Install Drip Line	$51.38	$51.38
	Labor Install Lateral Line	$38.54	$38.54
	Labor Install Mainline	$38.54	$38.54
	Install Drip Line Tractor use	$35.97	$35.97
	Install Main Tractor use	$53.95	$53.95
	Install Lateral Tractor Use	$35.97	$35.97
Other Costs			
	Water Reservoir	$77.07	$77.07
	Pipeline Ownership	$2.80	$2.80
	Water Withdrawal Permit	$28.03	$28.03
	GPS Unit		$41.11
	Cost-Share Program (35% of GPS)		$14.39
Total Costs		**$1,177.84**	**$1,297.80**

5.2.1.1 Financial Benefits and Costs

Financial effects of the adoption of the BMP are through two main sources: One, increased gross revenue from the crop through increased yields, and Two, change in the cost of production of tomatoes. Details on the cost of production and revenue from tomato production are presented in Appendix D.

Effect on crop yield: The most important financial change that can be brought about by adopting the BMP is the impact on the yield of tomatoes. While several studies have looked at yield differences between the two irrigation systems, results are mixed. Jaria (2013) evaluated these differences on the Leamington research site. Their findings indicated that there were no statistically significant yield differences between the two technologies. Tan et al. (2008) evaluated the difference between surface and subsurface drip irrigation on a 16-acre farm with sandy loam soil and using the same tomato cultivar in Harrow (a city located approximately 30 km southwest from Leamington). They found that under subsurface drip irrigation, there was a 5.3% increase in marketable tomato yields, when compared to surface drip irrigation. Tan et al. (2008) evaluated the two systems again in the same location, using the same tomato cultivar (Heinz 9478). They found that on the sandy loam soil, average marketable tomato yields over a 3-year period increased by 35 to 37% under the surface drip-broadcast fertilizer and surface-fertigated treatments relative to the non-irrigated control treatments, while average marketable tomato yields under subsurface-fertigated and subsurface-broadcast treatments increased by 43 to 47% relative to non-irrigated treatments (Tan et al. 2008).

These researchers showed that under different soil conditions (i.e., clay loam) the surface drip irrigation had higher yields when compared to subsurface irrigation. Because of the variability in the evidence on yield increases, in this study, the assumption of no yield increases from switching from surface to subsurface drip irrigation was made. Based on the data provided by the producer, the average tomato yield is 40 tonnes/acre. This is the quantity used for the revenue calculations of the baseline and BMP scenarios. For these calculations, the average tomato price was used, as indicated by the producer – $122 per tonne. For years two and three after the one in which tomatoes were grown, estimated revenues for seed corn and wheat were calcualted, since these crops are grown in rotation with field tomatoes. OMAFRA (2015) Field Crop Budgets were used to estimate the revenues and costs associated with these two crops.

Effect on cost of production: Based on data provided by the producer, annual irrigation costs under subsurface drip irrigation are lower when compared to surface drip irrigation. While the subsurface drip irrigation system is in place for three years, the surface drip irrigation is replaced every year. This reduces the irrigation costs significantly (Table 5.2).

Table 5.2. Difference in Annual Operating Cost per Acre under the Baseline and BMP Technology, for Tomato Production 2015 ($/acre)

Particulars	Baseline (Surface Drip)	BMP (Sub-surface Drip)	Difference (Baseline - BMP)
Revenue			
Gross Revenue	$4,892	$4,892	$0
Costs			
Land Preparation	$231	$231	$0
Cultural Practices	$1,330	$1,330	$0
Irrigation Costs	$918	$436	-$482
Harvesting	$461	$461	$0
Variable Costs	$2,940	$2,458	-$482
Fixed Costs	$904	$904	$0
Total Costs	$3,846	$3,363	-$482
Net Revenue	**$1,046**	**$1,528**	**$482**

Both technologies are similar except for the cost of providing water to the crop. As noted above the yield of tomato crop was assumed to be similar although some higher yields may be realized using the sub-surface drip irrigation. Under the baseline (surface drip irrigation technology) cost of providing water to the crop is the highest item of total cost (Figure 5.2).

Financial Desirability Indicators: As noted above two financial indicators were estimated for the study technology and compared with the baseline technology. Results are shown in Table 5.3. On both criteria – NPV and BCR the study technology (subsurface drip irrigation) is a more economically attractive alternative.

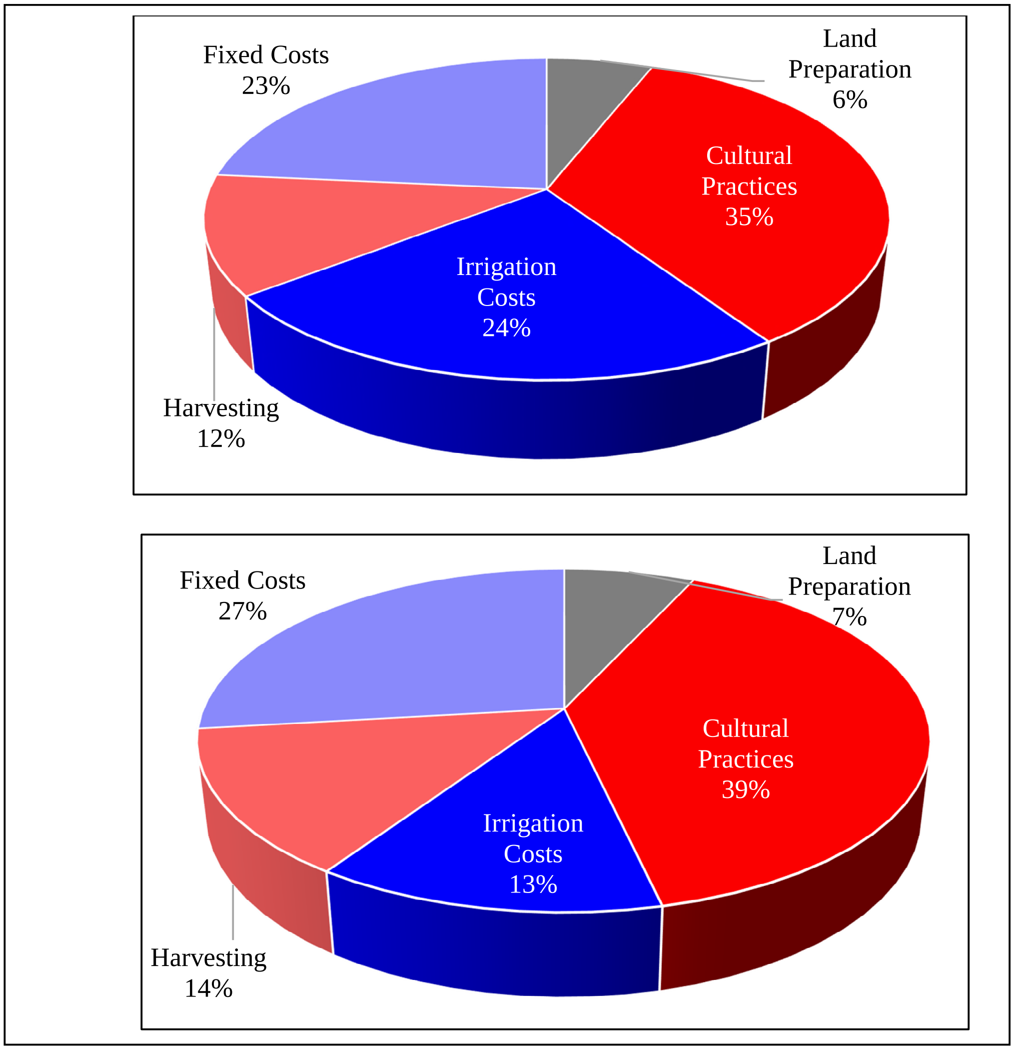


Figure 5.2. Distribution of Total Cost by Major Cost Categories, Baseline (Top) and BMP (Bottom), for Tomato Production

Table 5.3. Measures of Financial Desirability of Baseline and BMP Technology for Tomato Production ($/acre)

Particulars	**Baseline (Surface Drip Irrigation)**	**BMP (Subsurface Drip Irrigation)**
Net Present Value @ 5%	$5,450	$6,564
Present Value of Benefits	$30,298	$30,305
Present Value of Costs	$24,848	$23,741
Benefit- Cost Ratio	1.22	1.28

The impact of borrowing the funds required for this investment was also assessed. It was assumed that the grower borrowed 75% of the money, over 10 years at an annual interest rate of 4.75%. Under both scenarios, the change in NPV values are minimal – an increase of 0.4% over the no loan scenarios. This shows that irrespective of whether the grower borrows these funds or not, the profitability of the two water management systems does not change. Furthermore, when opportunity costs are taken into consideration, the difference in NPVs between the two technologies remains the same. The opportunity costs were included in a subsequent sensitivity analysis. In estimating these costs, the assumption made was that instead of investing in a new irrigation system, the farmer could have invested their money and gain a return. To estimate these costs, it was assumed that the farmer would alternatively use their funds for an investment with a guaranteed rate of return of 2.2%.

5.2.1.2 Environmental Benefits and Costs

Environmental effects were measured through change in GHG emissions, as well as through water and energy used. The first question posed was -- Does the adoption of a subsurface drip irrigation system lead to a decrease in GHG emissions in comparison to surface drip irrigation? Based on Edwards (2014), there were no statistically significant differences between the two irrigation systems. However, anecdotal evidence recorded for years 2012 and 2013 shows that in both years, fields under subsurface drip irrigation produced 14.47% and 18.32%, respectively, less GHG emissions when compared to surface drip irrigation (Table 5.4). On average, over the two growing seasons, GHG emissions were reduced by 16.8% under subsurface drip irrigation compared to surface drip irrigation. This reduction was explained as being due to sampling time temperature differences (Edwards, 2014). This would amount to a yearly difference of 1.29 CO_2-eq t/ha (0.52 CO_2-eq t/acre). In the financial evaluation of the two irrigation systems, differences in GHG emissions were not taken into consideration, as the producer received no benefits from their reduction.

The surveyed producer reported that they used the same amount of fertilizer and water, regardless of the irrigation system used. Since other farm operations are not different between the two technologies, no change in energy use was recorded. Previous studies have looked at the relationship between fertilizer use and various irrigation systems. Tan et al. (2003) found that when compared to surface drip irrigation, the buried (subsurface) system had higher nutrient N and P use efficiency.

Table 5.4. Difference in the GHG emissions from Baseline and BMP Technologies for Tomato Production, 2012-13

GHG	2012 Growing Season		2013 Growing Season	
	Baseline (Surface Drip Irrigation)	**BMP (Subsurface Drip Irrigation)**	**Baseline (Surface Drip Irrigation)**	**BMP (Subsurface Drip Irrigation)**
N_2O g/m2	0.35	0.17	0.40	0.42
CH_4 g/m2	-0.08	-0.08	-0.01	-0.01
CO_2 g/m2	517.24	479.24	805.47	628.61
CO_2-eq g/m2	617.75	528.38	923.80	754.55
CO_2-eq t/ha	6.18	5.28	9.24	7.55
CO_2-eq t/acre	2.50	2.14	3.74	3.05
Relative Difference		14.4%		18.3%

Source: Edwards (2014)

Jaria (2013) evaluated irrigation water use efficiency under the two systems and found no statistically significant differences between the two. European studies have also supported this conclusion (Martinez and Reca, 2014); although in terms of water use efficiency, the irrigation water amount was a statistically significant variable in the first two years but not in the third year (although there were clear differences, with subsurface drip irrigation having increased water use efficiency).

5.2.1.3 Indirect Benefits and Costs

Major indirect impact of the technology was measured in terms of labor requirements, leading to change in the leisure time available to the producer. The question raised was -- Does subsurface irrigation increase or decrease labour requirements, when compared to a surface drip system? Collected data supported the conclusion that compared to surface drip irrigation, the subsurface irrigation system requires less hired agricultural labour. This is in part due to the increased mechanization of the subsurface drip system, but also due to the fact that the retrieval of the system from the field is done once every three years, as opposed to every year, as it is the case with a surface drip irrigation system. However, differences related to labour requirements were incorporated in the financial analysis.

Related to the farmer’s leisure time, the question posed was -- Are there any farm owner lifestyle changes involved when moving from surface to subsurface drip irrigation? Based on our anecdotal evidence, from the case study farm, there is an increase in time spent by the farm owner or manager related to decision-making. The producer with the BMP technology indicated that the subsurface drip system requires more decision time and knowledge that is more specialized. The grower spends on average approximately 36 hours per growing season, gathering data, interpreting it and taking decisions regarding water needs. The farm operators’ labour costs were not accounted for in the financial analysis, because the evaluation of the economic return was done over three main factors of production: land, labour and capital.

5.2.1.4 Summary of Financial Analysis of the BMP for Tomato Production

Overall desirability of the BMP used to produce tomatoes could be cast in a sustainability paradigm. These are the major pillars of sustainable practices – economic, environmental and social. Results of this study suggest that the tomato production in Ontario using sub-surface irrigation is financially viable, it is similar to surface drip irrigation in terms of GHG emissions, and it diminishes leisure time for the producer (Table 5.5). The selection of a better technology among these two is highly dependent on bio-physical conditions, particularly water availability, levelling and type of soil, as well as operational logistic. The subsurface technology works better for sandy soils. This factor is an important determinant of economic benefits from the adoption of the technology. Furthermore, this surface drip irrigation technology can also create some logistical issues, such as access to the field for heavy machinery when the system is in place.

Table 5.5. Summary of Baseline and BMP Technologies for Tomato Production

Indicator	**Baseline (Surface Drip Irrigation)**	**BMP (Subsurface Drip Irrigation)**	**Difference in two Technologies (BMP – Baseline)**
Economic (NPV) ($/acre)	$6,204	$6,564	Positive increase
Economic (BCR) ($/acre)	1.26	1.28	Positive increase
GHG Emissions (CO_2-eq t/acre)	3.39	2.32	
Water Use	No change due to a change in farm practice		
Energy Use	No change due to a change in farm practice		
Social Impact (Leisure time)	++	-	Negative reduction

5.2.1.5 Sensitivity Analysis of the BMP for Tomato Production

Change in Crop Yield: As noted above, previous studies have shown that switching from surface drip irrigation to subsurface drip irrigation can lead to a yield increase. Jaria (2013) found that subsurface drip irrigation increased tomato yields by approximately 5%, whereas Tan et al. (2008) suggested these increases to be in the range of 8% and 10%. This sensitivity analysis involved varying yields according to these findings, as shown in Table 5.6.

As expected, a yield increase augments the difference between the two technologies in terms of net present value. Assuming that under subsurface drip irrigation tomato yield increases by 5%, relative to surface drip irrigation, the NPV increases by nearly 44% over the baseline scenario. The NPV increases by 59% and 69% over the baseline scenario, if tomato yield increases by 8% and 10%, respectively, under subirrigation (Table 5.6).

Table 5.6. Comparison of Financial Analysis of Baseline and BMP Technology at Different Tomato Yields

	Baseline (Surface Drip)	**BMP (Subsurface Drip)**			
		0%	**5%**	**8%**	**10%**
Net Present Value @ 5%	$5,450	$6,564	$7,835	$8,650	$9,193
Present Value of Benefits	$30,298	$30,305	$31,576	$32,391	$32,934
Present Value of Costs	$24,848	$23,741	$23,741	$23,741	$23,741
Benefit Cost ratio	1.22	1.28	1.33	1.36	1.39
NPV difference		$1,140	$2,385	$3,200	$3,743
% NPV increase from baseline		20.4%	43.76%	58.71%	68.67%

Change in crop price: Price received by producers can have a significant impact on the economics of a crop. Tomatoes are no exception. For the baseline scenario, the price for field-grown tomatoes was assumed to be $122 per tonne. The price sensitivity analysis conducted, assumed a reduction in commodity price by 2 to 7%. These estimations were used to evaluate the profitability of subsurface drip irrigation, as shown in Table 5.7. Sensitivity analysis results indicate that even with a tomato price decrease of up to 7%, the BMP remains a viable option financially, outperforming the baseline scenario technology.

Table 5.7. Comparison of Financial Analysis of Baseline and BMP Technology at Different Tomato Prices

	0%	-2%	-6%	-7%
Baseline (Surface Drip)				
Net Present Value @ 5%	$5,450	$4,912	$3,778	$3,477
Present Value of Benefits	$30,298	$29,760	$28,626	$28,325
Present Value of Costs	$24,848	$24,848	$24,848	$24,848
Benefit Cost ratio	1.22	1.20	1.15	1.14
BMP (Subsurface Drip)	**0%**	**-2%**	**-6%**	**-7%**
Net Present Value @ 5%	$6,564	$6,019	$4,885	$4,584
Present Value of Benefits	$30,305	$29,760	$28,626	$28,325
Present Value of Costs	$23,741	$23,741	$23,741	$23,741
Benefit Cost ratio	1.28	1.25	1.21	1.19
NPV increase over Baseline	20.44%	22.54%	29.30%	31.84%

Change in discount rate: Increasing the discount rate from 5% to 10% and further to 15% resulted in increasing the gap between the financial performances of the two technologies. However, discounting future costs and benefits associated with surface and subsurface drip irrigation more heavily did not result in either of the technologies being financially unattractive. At a discount of 5%, the profitability of tomato production, using NPV indicator, under subsurface drip irrigation was approximately 20% higher compared to surface drip irrigation. At discount rates of 10% and 15%, the increase over the baseline scenario was nearly 21% and over 21%, respectively, as shown in Table 5.8. The lower initial investment cost is one of the reasons for these small changes in the BCR at different discount rates.

Change in investment cost: A recent study looking at subsurface drip irrigation in Ontario for a corn farm located in Norfolk County estimated the initial cost of investment for this system at $1,874 per acre (Jacques, 2014). This cost estimate is 48% higher than the capital investment cost used for the case study. The differences in initial cost might be a result of differences in in terms of soil type and leveling, as loamier and unleveled fields require additional adjustments, and thus result in higher cost of investing in subsurface drip irrigation. To ensure robustness of results, the NPV values for subsurface drip irrigation were calculated at a 15%, 25%, 35 and 45% increase in the initial cost of the system. Compared to the baseline technology, subsurface drip irrigation remains more profitable; however, the gap between the two technologies gradually diminishes as the capital investment cost increases (Table 5.9). Even with an increase of 45% in the capital cost of subsurface drip irrigation, the NPV of this technology is approximately 10% higher than that of surface drip irrigation.

Table 5.8. Comparison of Financial Results for the Baseline and BMP Technology for Tomato Production at Different Discount Rates

Baseline (Surface Drip)			
	5%	**10%**	**15%**
Net Present Value	$5,450	$3,840	$2,838
Present Value of Benefits	$30,298	$22,313	$17,290
Present Value of Costs	$24,848	$18,473	$14,452
Benefit Cost ratio	1.22	1.21	1.20
BMP (Subsurface Drip)			
	5%	**10%**	**15%**
Net Present Value	$6,564	$4,639	$3,442
Present Value of Benefits	$30,305	$22,317	$17,292
Present Value of Costs	$23,741	$17,677	$13,850
Benefit Cost ratio	1.28	1.26	1.25
NPV increase over Baseline	20.44%	20.80%	21.28%

Table 5.9. Comparison of Baseline and BMP Technology for Tomato Production at Different Capital Investment Costs

	Baseline (Surface Drip)	**BMP (Subsurface Drip)**			
		15%	**25%**	**35%**	**45%**
Net Present Value @ 5%	$5,450	$6,370	$6,241	$6,111	$5,982
Present Value of Benefits	$30,298	$30,305	$30,305	$30,305	$30,305
Present Value of Costs	$24,848	$23,935	$24,065	$24,194	$24,324
Benefit Cost Ratio	1.22	1.27	1.26	1.25	1.25
NPV increase over Baseline ($)		$920	$790	$661	$531
NPV increase over Baseline (%)		16.87%	14.50%	12.12%	9.74%

Change in farm size: The case study farm had a total size of approximately 1,000 acres, of which 110 acres were under irrigation – half under surface drip irrigation, and the other half under subsurface drip irrigation. In the previous sensitivity analyses, financial performance was estimated under this small proportion (11% of total farm size) under the crop. In this sensitivity analysis, this assumption was modified to smaller sized farms. It was assumed that these farms had 40 acres under irrigation (20 acres under subsurface drip irrigation, and the rest under surface drip irrigation), and that the total farm size varied between 60 acres and 500 acres. The provincial average size for a field grown tomato production farm is of 125 acres, with approximately 20 acres under tomato cultivation. Results summarized in Table 5.10 show that while the NPV value of this investment remains positive, profit margins decrease more as farm size decreases. This difference can be explained by the fact that in the case of the GPS and water reservoirs, the costs were divided over the entire farm size.

Table 5.10. BMP Technology at Different Farm Sizes for Tomato Production ($/acre)

	BMP (Subsurface Drip)				
	1,000 acres	500 acres	250 acres	125 acres	60 acres
Net Present Value @ 5%	$6,564	$5,343	$4,730	$4,355	$3,504
Present Value of Benefits	$30,305	$30,305	$30,305	$30,305	$30,305
Present Value of Costs	$23,741	$24,963	$25,575	$25,950	$26,801
Benefit Cost ratio	1.28	1.21	1.18	1.17	1.13

5.2.2 Financial Analysis of BMP for Cranberry Production

The second case study focused on the financial evaluation of changing water table management with the use of an improved drainage system and tensiometers, on a farm growing cranberries for the fresh market and for processing. As noted in Chapter 4, it was a farm of 567 ha (1,400 acres) located in Saint-Louis-de-Blandford, Québec. The farm is dedicated exclusively to the cultivation of cranberries. The grower used a sprinkler system throughout the production area to irrigate and for frost protection. The cranberry beds are surrounded by ditches, which together with the drainage system and water control structures, allow for water table management.

Only recently, the producer improved the drainage system on a subsection of the farm, together with the introduction of tensiometers, in order to improve water table management and to trigger irrigation more accurately. Historically, the producer was using only sprinkler irrigation without consideration of the upward flux from the water table. The plots were irrigated 2 hours every other day without monitoring the water table depth. Recently, the producer started to use tensiometers to control water table depths. A field experiment conducted by Pelletier et al. (2015), during the 2011 and 2012 growing seasons, showed that the producer's practice of irrigating cranberry fields every other day for 2 hours exceeded plant water requirements. Over-irrigated soils create wet conditions, which deprive the roots of oxygen, negatively affecting cranberry yields. For this case study, a relatively wet water management practice was compared with a drier management practice.

The improved water management system was used on a subsection of the farm. For the purpose of this analysis, it was assumed that the grower adopted this practice on approximately 80 ha (200 acres), which accounts for nearly 14% of the cultivated surface of the farm. Cranberries are not grown in a crop rotation. The Stevens cultivar is the one that was grown predominately by this producer. Cranberries are grown on beds, with the following dimensions 457m x 46m (1,496 feet by 151 feet). Irrigation lines are placed on cranberry beds, at a distance of 15m, and sprinkler heads are positioned 18m apart (Pelletier et al., 2015). Subsurface drainpipes were installed at a depth of 80cm about 11m apart, on a 0.07 slope (Pelletier et al., 2013).

Wet conditions, like the one encountered on the case study farm, can be addressed in different ways, depending on the primary issue triggering the problem unleveled soil topography, poor drainage due to clogged drains or ditches, too distantly spaced drains, poor cranberry bed design, over irrigation. According to Jabet et al. (2016), most of these issues can be addressed by either doubling the number of drain tiles available in a cranberry bed. In fact, Caron et al. (2017) has mentioned that in newer fields drain spacing is done at 6m, or by cleaning clogged ditches or by digging new ones. In addition, another change involves changing the managerial practice regarding triggering irrigation and measuring water tables. The grower in the case study reported irrigating 2 hours/day, irrespective of the water table status. However, this was measured neither accurately nor periodically.

The above provided the premises that were used to build the baseline scenario of this case study: (i) the grower irrigates twice every other day; (ii) subsurface drains are installed 10m apart; (iii) no device is used to inform the triggering of irrigation; and (iv) sprinkler irrigation system is used for irrigation. In the BMP scenario, cranberry production was under an optimal, or a relatively drier, water management treatment. For the BMP scenario, it was assumed that most of the infrastructure remained the same, apart from irrigation triggering and subsurface drainpipes distancing. In terms of irrigation triggering, the assumption made was that the grower changed to using tensiometers (model HXM80, Hortau, Lévis, Canada). In terms of subsurface drainpipes, it was assumed that the grower invested in improving drainage by increasing the number of drainpipes per cranberry bed – spacing distance of 6m.

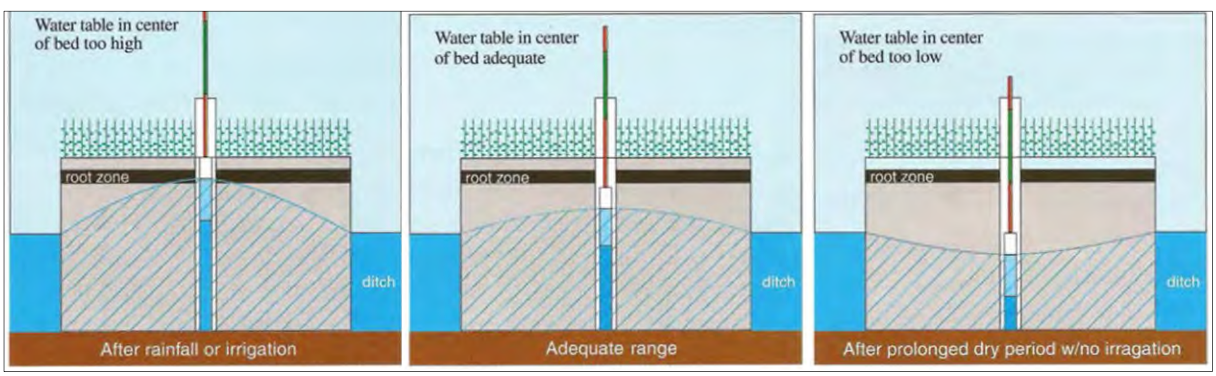
The cranberry water management systems consisted of a water reservoir located on the highest elevation point of the farm. The reservoir is filled by precipitation and water from the Becancour River with the use of a water pump. The cranberry fields are supplied gravitationally with water, via the main canal. From the canal, a main pipeline brings the water into the cranberry beds, via lateral pipelines. There are few areas on the farm where a low flow pump is needed for water to reach the main pipeline. For each bed, there are three laterals, 15m apart, with 25 sprinkler heads on each one of the laterals. The beds are surrounded by perimeter ditches, and each bed has at least a control structure in place. Embedded at a depth of 80 cm are the drainpipes, 11m apart for the baseline and 6m apart for the BMP scenario. It was assumed that for the BMP scenario the grower had to install more drainpipes, which led to an increased cost of investment and a loss of yield of 10% over the first two years following new drains installation. These impacts are similar to those reported by Jabet et al. (2016). Furthermore, under the BMP scenario, tensiometers were used monitor water tables accurately and to trigger irrigation. Figure 5.3 shows an image of the sprinkler irrigation system and a water collection reservoir, which is the place where water is decontaminated of pesticides and then released in river, or most times recirculated and reused on the farm. Different scenarios of water table levels, with the optimal level in the middle image, are shown in Figure 5.3.

The cost of investment associated with these two water management systems, are detailed in Table 5.11 below. For the calculation of these prices, it was assumed that 80 ha (200 acres) were under the BMP scenario. The total cost the baseline system was $2,257/acre ($5,578/ha), whereas the BMP system the cost of investment was $2,949/acre ($7,288/ha). The cost of investment was derived using the producers layout and specification, and using price guideline document, AGDEX 233/821, developed by CRAAQ (2017), and some were obtained through personal communication with the grower, with Vincent Pelletier and Jean Caron, while others from the recent work of Jabet (2013), Jabet et al. (2016), Pelletier et al. (2013, 2015) and Caron et al. (2017). The cost of tensiometers was derived from a personal communication with C. Letendre from Hortau, Lévis located in Québec and through personal communication with J. Caron, who provided additional information and shared Jabet et al. (2016) calculations on tensiometer costs.

To better distinguish between these two scenarios of analysis, the baseline water management system will be referred to from here on as the wet scenario, and the BMP scenario as the dry scenario.

Source: APCQ (2018)

Figure 5.3. Sprinkler irrigation system and field drainage to collection pond



Source: Sandler and DeMoranville (2008)

Figure 5.4. Water Table Management at Three Different Levels: Too High, Optimal and Too Low

Table 5.11. Cost of Investment for Baseline and BMP System for Cranberry Production ($/acre)

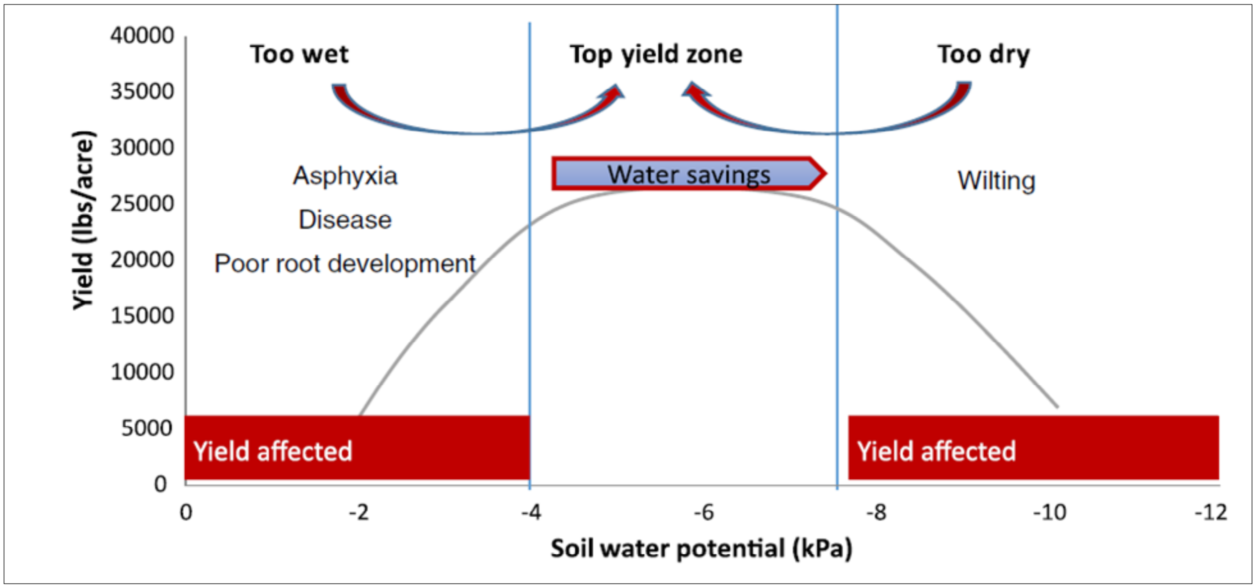
Items	Baseline (Wet)	BMP (Dry)
Drainage system	$267	$769
Water reservoir	$458	$458
Irrigation system	$631	$631
Field water control structures	$223	$223
Reservoir water control structures	$98	$98
Ditch water control structures	$29	$29
Irrigation pump (diesel)	$231	$231
Low lift pump (diesel)	$321	$321
Tensiometers Monitoring Station		$123
Web Base		$36
Repeater		$21
Installation Fee Monitoring Station		$5
Installation Fee Web Base		$3
Installation Fee Repeater		$1
Total Costs	**$2,257**	**$2,949**

5.2.2.1 Financial Benefits and Costs

Similar to tomato production case study, financial performance of cranberry production is also affected by two major faros – yield and cost of production. A detailed cost of production and revenue from cranberries is presented in Appendix E.

Effect on crop yield: Keeping water table levels in the optimal range, increases cranberry yields, when compared to a relatively high-water table management strategy. Several researchers evaluated yield differences between optimal and relatively wet water management conditions in cranberry production and found consistent results. Pelletier (personal communication 2015) evaluated the yield response to different water management practices, on the case study farm (Pelletier et al., 2016), the average yield on a 5-years period prior, under the grower's traditional water management practice, was 35,000 ± 5,975 lbs/acre (39,230 ±6,697 kg/ha). In 2014, with optimal water management, cranberry yield increased by 51%, the average yield was 52,902±2,868 lbs/acre (59,295±3,215 kg/ha).

Poor drainage in cranberry fields can be either due to clogged pipelines, or due to suboptimal system installation. Yield losses associated with the first issue have been found to reduce yields by 39%, whereas in the case of suboptimal drainage system installation it reduced yields by 25% (Pelletier et al., 2017). The effect of different water table levels on cranberry yields is illustrated in Figure 5.5 (Jabet et al., 2016). A recent paper by Jabet et al. (2016) discusses yield implications, when correcting for wet conditions in cranberry fields. Improving sub optimally drained field has been shown to increase cranberry yields by 5,000 lbs/acre (5,588 kg/ha).



Source: Jabet et al., (2016)

Figure 5.5. Cranberry Yield Variation by Soil Water Potential

Cranberry costs of production were estimated using data provided by the grower. The baseline budget was calculated using the average of the 2011-2014 production period. The case study farm budget was then compared to the benchmark cost of production in AGDEX 233/821 produced by CRAAQ (2017). While the case study farm was substantially larger than that used for benchmark, the costs and benefits were proportionally similar. These benchmark estimates were also used to estimate the cost of production under the BMP scenario.

For the baseline scenario, it was assumed that cranberry yields were 35,000 kg/ha (31,266 lbs/acre), which represented the growers' average over the last four years before any changes in the water management system were made. Under the BMP scenario, only a 16% yield increase was assumed, which is a similar increase to the one used by Jabet et al. (2016). Results are summarized in Table 5.12.

Table 5.12. Difference in Cost per Acre under the Baseline and BMP System for Cranberry Production, 2015 ($/acre)

Particulars	**Baseline (Wet)**	**BMP (Dry)**	**Difference (Baseline-BMP)**
Revenue			
Gross Revenue	$6,447	$7,500	-$1,053
Costs			
Land Preparation	$338	$338	$0
Cultural Practices	$1,094	$1,094	$0
Irrigation Costs	$728	$591	$137
Harvesting	$312	$312	$0
Other Costs	$422	$480	-$58
Variable Costs	$2,895	$2,816	$79
Fixed Costs	$1,466	$1,466	$0
Total Costs	$4,361	$4,282	$79
Net Revenues	$2,086	$3,218	-$1,132

Effect on cost of production: The BMP affected the cost of production through irrigation cost. Based on average summer rainfall calculation, 74% water savings are expected under a dry treatment (152 mm) when compared to a wet treatment (593 mm) (Pelletier et al., 2013; Jabet et al., 2016). Our irrigation costs calculations were based on these figures, as Pelletier et al. (2013), conducted his research on the same case study farm. The annual irrigation costs per acre under the baseline scenario were estimated to be $728 ($1,800/ha), which reduced to $591/acre ($1,461/ha) under the BMP scenario. Both labour and energy costs are included in these estimates. These values suggest that there is a reduction of $79/acre in costs under an improved water management scenario over the baseline.

Cranberry production costs for each of the scenarios are shown in Table 5.12. Both technologies are similar except for revenues, cost of irrigation, other costs and initial cost of investment. As shown in Figure 5.6, cultural practices account for over 38-39% of the total costs of production, followed by irrigation costs. In fact, irrigation costs constituted 25% of the total cost under the baseline scenario, which was reduced to 21% under the BMP scenario.

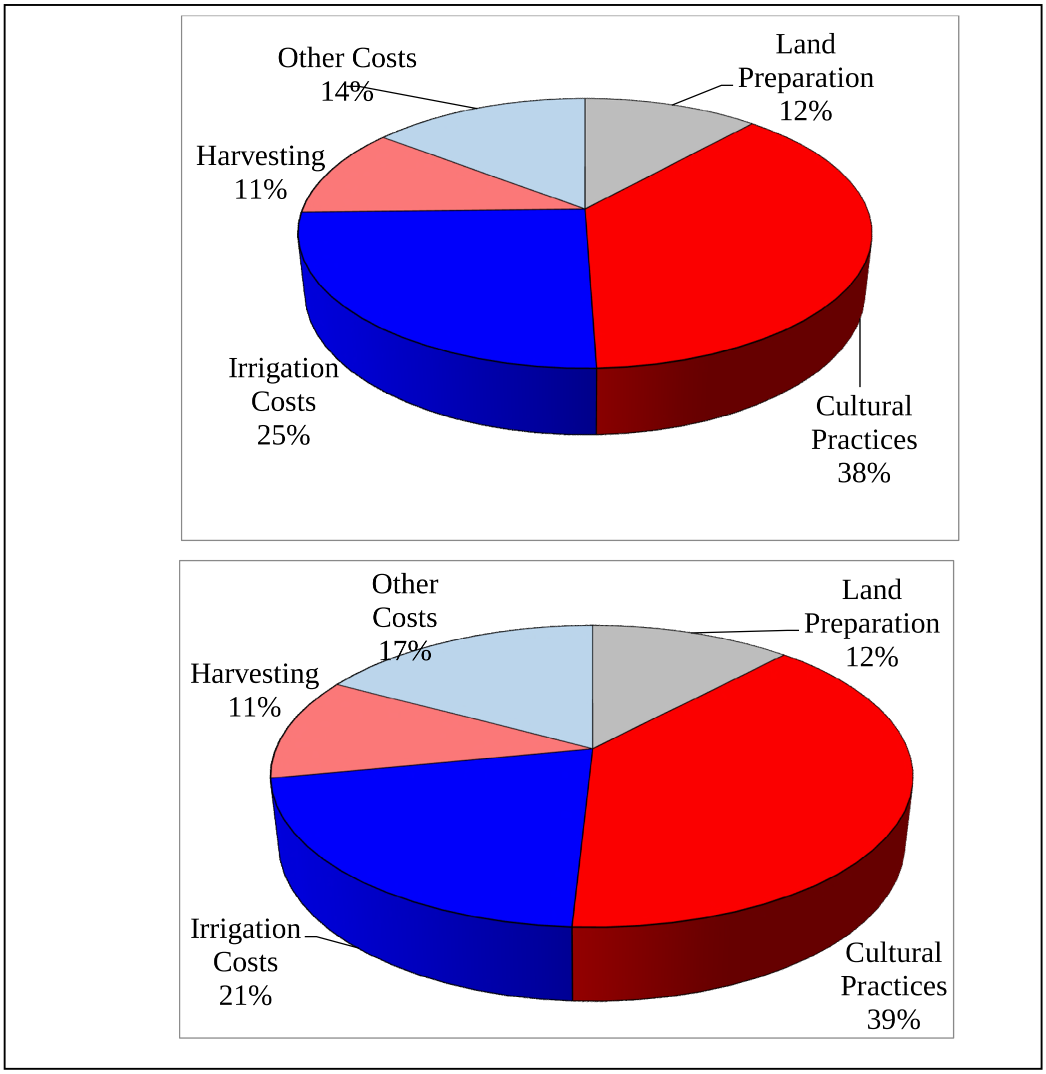


Figure 5.6. Distribution of Total Cost by Major Cost Categories, Baseline technology (Top) and BMP Technology (Bottom) for Cranberry Production

Economic Desirability Indicators*:* As noted above three financial indicators were estimated for the BMP technology and compared with those for the baseline technology. Results are shown in Table 5.13. Based on both the criteria – NPV and BCR, the improved water management system outperforms the baseline practice followed by the producer. Under a drier water management regime, the net present value per acre was estimated at $39,223, almost 53% higher than that under the baseline scenario. For the financial analysis, it was assumed that the farmers had an opportunity cost of 2.2%. Furthermore, in the analysis the assumption was that the producer did not acquire a loan for the funding of this project. However, in a sensitivity analysis, 75% of the cost of investment was assumed to be borrowed. Since these were like those of this analysis, the assumption of no loan for capital investment was maintained. Results shown in Table 5.13 indicate that the NPV of the baseline scenario was taken – $NPV_{Baseline}$ was 25,700 $/acre and NPV_{BMP} was 39,223 $/acre, an increase of 53% over the baseline scenario; benefit-cost ratios were 1.42 and 1.64 for the baseline and BMP scenarios respectively.

Table 5.13. Measures of Financial Desirability of Baseline and BMP System for Cranberry Production ($/acre)

Particulars	**Baseline (Wet)**	**BMP (Dry)**
Net Present Value @ 5%	$25,700	$39,223
Present Value of Benefits	$86,795	$100,973
Present Value of Costs	$61,095	$61,750
Benefit Cost Ratio	1.42	1.64

5.2.2.2 Environmental Benefits and Costs

Environmental benefits or damages were measured through change in GHG emissions, as well as through water and energy used. Grant (2014) evaluated the difference between GHG emissions stemming from two distinct treatments/conditions – (i) organic soil where the water table was held higher, which created a wetter treatment; and (ii) mineral soil where the water table was held to be relatively dry. This study reported that the fields flooded over a longer period of time emitted more carbon dioxide and methane, when compared to those that are flooded but quickly drained. However, Grant (2014) reported no statistically significant differences between the two water management treatments. However, anecdotal evidence recorded for years 2012 and 2013 showed that during the 2012 growing season, organic fields under a relatively wet water management regime, produced 4% less GHG emissions when compared to mineral soils under a relatively dry water management regime (Table 5.14). In the subsequent growing season, cranberry production under a relatively wet water management treatment produced 11% more GHG emissions when compared to the dry treatment. The relative difference between the two treatments, over the two growing seasons is of 3%, with fields under a dry treatment producing less GHG emissions when compared to fields under a wet treatment. In the financial evaluation of the two treatments – wet and dry water management treatments, differences in GHG emissions were not taken into consideration.

Table 5.14. Difference in the GHG Emissions per acre from Baseline and BMP System for Cranberry Production, 2012 and 2013

GHG	**2012 Growing Season**		**2013 Growing Season**	
	Organic Soil Relatively Wet	Mineral Soil Relatively Dry	Organic Soil Relatively Wet	Mineral Soil Relatively Dry
N_2O g/m^2	0.001	0.004	-0.003	0.001
CH_4 g/m^2	0.063	0.197	0.048	0.041
CO_2 g/m^2	168	170	143	127
CO_2-eq g/m^2	170	177	144	128
CO_2-eq t/ha	1.70	1.77	1.44	1.28
CO_2-eq t/acre	0.69	0.72	0.58	0.52
Relative Difference		4%		-11%

Source: Grant (2014)

A study by Pelletier et al. (2013) looked at water use and water productivity (yield per area cultivated per depth of rainfall and irrigation), associated with cranberry production under wet[18] and dry treatments. Their results showed that over the 2011-2012 growing seasons, water savings of 21% to 93% were obtained, under dry treatment, as compared to wet treatment. In addition, Jabet et al. (2016) have suggested that based on average summer rainfall calculation, 74% water savings are expected under a dry treatment (152 mm) in comparison to a wet treatment (593 mm).

5.2.2.3 Social Benefits and Costs

Major social impact of the technology was measured in terms of labor requirements and leisure time available to the producer. As expected, when compared to a relatively wet treatment – with irrigation taking place every other day for 2 hours, a drier treatment requires less hired agricultural labour and based on our anecdotal evidence, from the case study farm, there is an increase in time spent by the farm owner or manager related to decision-making. Precise estimate of the time saved is not available.

[18] Site B in this report is this study farm. The control treatment for this site consisted of 2 hours of irrigation every two days. There was no additional wet treatment for this site, because the control treatment was considered to be wet.

5.2.2.4 Summary of Financial Analysis of Cranberry Production Systems

Summary findings for cranberry production under a baseline and BMP scenario indicate that from a purely financial standpoint, adopting an improved water management system increases NPV by almost 53% over and above the baseline technology. While not quantitatively assessed, reduction in production risks, those through water availability, and right timing, should also be considered as potential positive effects of the alternative management system. Beyond the economic benefits, cranberry fields under a drier treatment, decrease in GHG emissions. Furthermore, water and fuel use also decrease under the BMP scenario. Results of this case study are summarized in Table 5.15.

Table 5.15. Summary of Baseline and BMP System for Cranberry Production

Indicator	**Baseline (Wet)**	**BMP (Dry)**	**Difference (BMP– Baseline)**
Economic (NPV) ($/acre)	$25,700	$39,223	Positive increase
Economic (BCR) ($/acre)	1.42	1.64	Positive increase
GHG Emissions (CO_2-eq t/acre)	0.61	0.57	Positive reduction
Water Use (mm)	593	152	Positive reduction
Energy Use (liters of fuel/acre)	123	31	Positive reduction
Social Impact (leisure time)	+	-	Negative decrease

5.2.2.5 Sensitivity Analysis of Cranberry Production Systems

Similar to tomato production BMP, financial analysis results can be sensitive to changes in the baseline parameters used. Four such parameters selected for this sensitivity analysis were cranberry yield, rainfall change, cranberry prices, discount rates, initial capital costs, and farm size variation.

Change in Crop Yields: The first sensitivity analysis involved varying yields to ensure the robustness of the base financial analysis. Cranberry yields can be affected by pruning of the plant, natural plant development, drainage system maintenance (i.e., unclogging), among others. Because of lack of better data, it was assumed that the yields under the improved water management system would increase only by 5%, followed by a 10% and 15% increase. Results of the analysis are presented in Table 5.16.

Table 5.16. Comparison of Financial Performance Baseline and BMP System at Different Cranberry Yields ($/acre)

	Baseline (Wet)		**BMP (Dry)**	
		5%	10%	15%
Net Present Value @ 5%	$25,700	$29,385	$33,724	$38,064
Present Value of Benefits	$86,795	$91,135	$95,474	$99,814
Present Value of Costs	$61,095	$61,750	$61,750	$61,750
Benefit Cost ratio	1.42	1.48	1.55	1.62
NPV difference		$3,685	$8,025	$12,365
NPV increase from baseline		14.34%	31.23%	48.11%

Results of this financial measures for the study suggest that the relatively dry treatment continues (BMP scenario) to be more affordable when compared to the relatively wet treatment, even when the yield increases are in the magnitude of 5%. Comparatively, the BMP scenario increases the NPV by over 14% over the baseline practice. Furthermore, the benefit-cost ratio is also higher for the BMP scenario. Even at an increase of 1% in yield, the BMP scenario outperforms the baseline in terms of NPV ($25,913/acre), even though it has the same benefit to cost ratio as the baseline.

Change in the level of rainfall: In the base economic analysis, average rainfall of 233 mm was used. Under these conditions, irrigation costs were estimated following Jabet et al. (2016). For this sensitivity analysis, costs and benefits were evaluated under dry (148 mm) and wet (355 mm) growing seasons. Irrespective of the amount of summer rainfall, the improved water management system outperforms the baseline practice financially. Difference between the two technologies (58%) is noted for the dry summers, whereas during wet summers that gap decreases to almost 48%, as shown in Table 5.17.

Change in crop price: Depending on the processor and market conditions where cranberries are sold, their price can vary. In the base analysis, the price for frozen berries was assumed to be $0.45 /kg, and $1.08 /kg for the fresh market cranberries. One of the main concerns of growers has been the almost continual decline in cranberry prices (as shown in Figure 2.6), which was also confirmed by regional agricultural experts. To understand the potential effect of a change in prices on profitability, a decrease of up to 20% in cranberry prices was assumed. The NPV values were re-estimated under this assumption. As expected, NPV decreases as cranberry prices decrease.

However, even then, both water management systems remain profitable, although the gap between NPV values for the two scenarios increases. When prices decrease of 20% was assumed, (i.e., 0.36 $/kg for frozen berries, 0.86 $/kg fresh market and 0.03 $/kg premium price), the NPV increase over the baseline scenario is of 83% (Table 5.18).

Table 5.17. Comparison of Baseline and BMP System for Cranberry Production at Different Rainfall Levels

Baseline (Wet)			
	Dry	Average	Wet
Net Present Value	$24,670	$25,700	$26,729
Present Value of Benefits	$86,795	$86,795	$86,795
Present Value of Costs	$62,125	$61,095	$60,066
Benefit Cost ratio	1.40	1.42	1.44
BMP (Dry)			
	Dry	Average	Wet
Net Present Value	$38,902	$39,223	$39,542
Present Value of Benefits	$100,973	$100,973	$100,973
Present Value of Costs	$62,071	$61,750	$61,431
Benefit Cost ratio	1.63	1.64	1.64
NPV change over Baseline	57.69%	52.62%	47.94%

Table 5.18. Comparison of Baseline and BMP System at Different Cranberry Prices

			Baseline (Wet)		
	Base	-5%	-10%	-15%	-20%
Net Present Value	$25,700	$22,477	$19,255	$16,033	$12,811
Present Value of Benefits	$86,795	$83,573	$80,350	$77,128	$73,906
Present Value of Costs	$61,095	$61,095	$61,095	$61,095	$61,095
Benefit- Cost Ratio	1.42	1.37	1.32	1.26	1.21
			BMP (Dry)		
	Base	-5%	-10%	-15%	-20%
Net Present Value	$39,223	$35,292	$31,361	$27,429	$23,498
Present Value of Benefits	$100,973	$97,042	$93,111	$89,179	$85,248
Present Value of Costs	$61,750	$61,750	$61,750	$61,750	$61,750
Benefit- Cost Ratio	1.64	1.57	1.51	1.44	1.38
NPV change over baseline	$13,523	$12,814	$12,106	$11,397	$10,688
	52.62%	57.01%	62.87%	71.08%	83.43%

Change in discount rate: Relative differences between the financial measures for the two scenarios (dry vs. wet treatments) were estimated by using a discount rate of 5%, and then increasing it to 10% and 15%. Discounting future costs and benefits associated with relatively dry and wet treatments more heavily increased the gap between NPVs for the two scenarios slightly, with the BMP scenario having higher net returns. At a discount rate of 5%, the profitability of cranberry production under a BMP scenario, as estimated by NPV, is approximately 53% higher than that under the baseline scenario. At discount rates of 10% and 15%, the increase over the baseline scenario is 52.05% and 51.51% respectively (Table 5.19).

Change in investment cost: Recent studies (e.g., [Caron et al., (2017)], have suggested common issues associated with poor drainage in cranberry fields. The cost of fixing these problems have also been reported by Jabet et al., (2016), which suggests that the initial cost of investment varies depending on the issue that requires correction. To ensure robustness of results, the NPV values for the BMP scenario was estimated by assuming that the costs of investment increases by 10%, 15% and 20%.

Table 5.19. Comparison of Baseline and BMP System for Cranberry Production at Different Discount Rates ($/acre)

	Baseline (Wet)		
	5%	10%	15%
Net Present Value	$25,700	$17,550	$12,910
Present Value of Benefits	$86,795	$61,337	$46,803
Present Value of Costs	$61,095	$43,787	$33,893
Benefit Cost ratio	1.42	1.40	1.38
	BMP (Dry)		
	5%	10%	15%
Net Present Value	$39,223	$26,685	$19,561
Present Value of Benefits	$100,973	$71,356	$54,448
Present Value of Costs	$61,750	$44,671	$34,888
Benefit Cost ratio	1.64	1.60	1.56
NPV change over Baseline	52.62%	52.05%	51.51%

Compared to the baseline technology, the improved water management system remains more profitable; however, the gap between the two technologies diminishes gradually as the capital investment cost increases (Table 5.20). Even with an increase of 20% in the capital cost of improved water management system, production under this scenario results in an NPV over 50% higher than that for the baseline.

Table 5.20. Comparison of Baseline and BMP System at Different Capital Investment Costs for Cranberry Production ($/acre)

	Baseline (Dry)	**BMP (Wet)**			
		0%	10%	15%	20%
Net Present Value @ 5%	$25,700	$39,223	$38,928	$38,780	$38,633
Present Value of Benefits	$86,795	$100,973	$100,973	$100,973	$100,973
Present Value of Costs	$61,095	$61,750	$62,045	$62,192	$62,340
Benefit-Cost Ratio	1.42	1.64	1.63	1.62	1.62
NPV increase over Baseline ($)		$13,523	$13,228	$13,081	$12,933
NPV increase over Baseline (%)		52.62%	51.47%	50.90%	50.33%

Table 5.21. Comparison of Baseline and BMP System at Different Farm Sizes for Cranberry Production ($/acre)

Baseline (Wet) Area of the Farm				
	1,400 acres (1,065 acres)	964 acres (321 acres)	482 acres (161 acres)	241 acres (80 acres)
Net Present Value @ 5%	$25,700	$25,458	$20,875	$19,688
Present Value of Benefits	$86,795	$86,795	$111,550	$111,550
Present Value of Costs	$61,095	$61,337	$90,676	$91,862
Benefit-Cost Ratio	1.42	1.42	1.23	1.21
BMP (Dry) Area of the Farm				
	1,400 acres (1,065 acres)	964 acres (321 acres)	482 acres (161 acres)	241 acres (80 acres)
Net Present Value @ 5%	$39,223	$39,222	$38,309	$37,123
Present Value of Benefits	$100,973	$100,973	$129,399	$129,399
Present Value of Costs	$61,750	$61,751	$91,090	$92,276
Benefit-Cost ratio	1.64	1.64	1.42	1.40

Change in farm size: The base financial analysis was undertaken for the case study farm of approximately 1,400 acres (567 ha), of which 1,065 acres (431 ha) were under production. A change in the farm size was used in this sensitivity analysis. In this sensitivity analysis, it was assumed that these farms had 80 to 321 acres (33 ha to 130 ha) under production, and that the total farm size varied between 241 acres and 964 acres (98 ha to 390 ha). A representative (based on Census data) cranberry farm for the region is of 482 acres (195 ha), with approximately 161 acres

(65 ha) under cultivation. Results show that while the NPV value of this investment remains positive, profit margins decrease more as farm size decreases (Table 5.21).

5.2.3 Financial Analysis of Onion Production

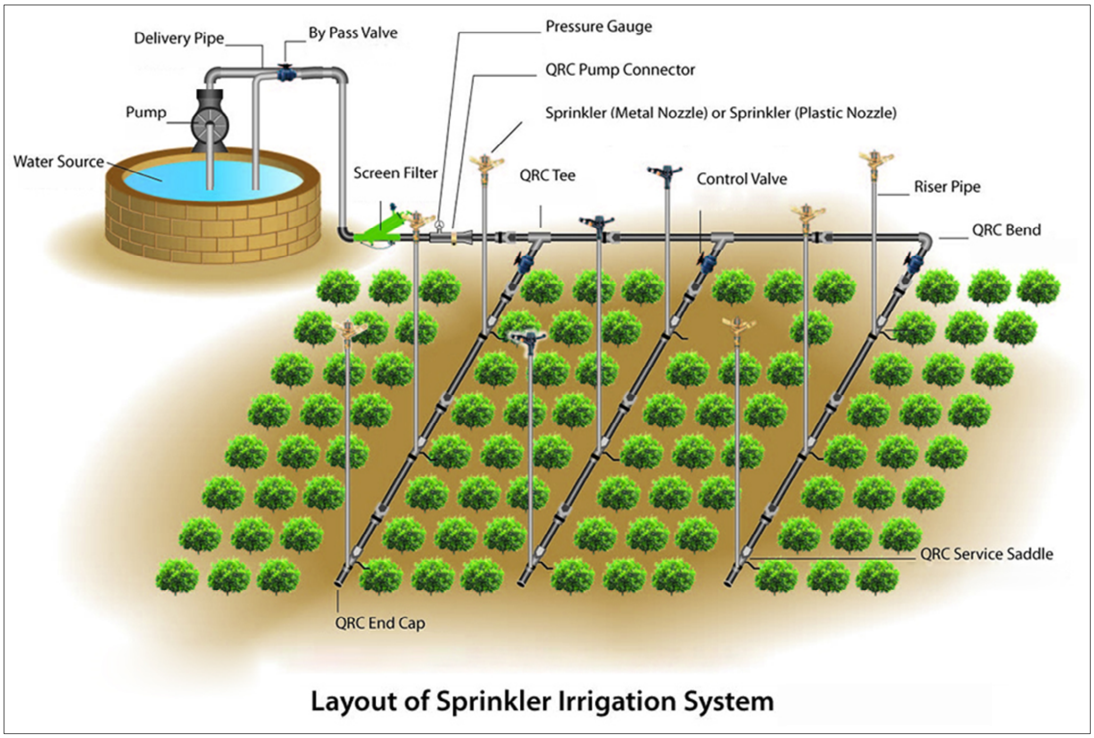
The third financial evaluation was for onion production in Québec. It involved investing in sprinkler irrigation and comparing it to dryland production system following a mixture of onions and carrots. As noted above, this farm had 607 ha (1,500 acres) of land and was located in Saint-Patrice-de Sherrington, in Montérégie, Québec. Approximately 23% of the farm area was dedicated to onions and carrots cultivation (350 acres or 142 ha). The grower used sprinkler irrigation as a water management system.

Onions and carrots are grown in an intercropping basis following a two-year crop rotation with lettuce and spinach. Onions are grown on raised beds, with the following dimensions 1.83m x 9m (6 feet by 30 feet). The farm section dedicated to onion production is done on highly decomposed organic matter soil (Lloyd, 2016). Water sources for irrigation are mixed, with some water coming from an on-farm well, and recently from an on-farm reservoir.

The case study producer uses sprinkler irrigation system (BMP technology) throughout the onion production area. In general, regardless of whether it is a dry, normal or wet season, the producer only irrigated onions once per growing season, early in the season during the onions germination phase. Irrigation water was supplied using two large electric pumps (one of 200hp and another one of 60hp) and occasionally using a smaller diesel pump of 30 hp. For the most part, the first electric pump was used.

The sprinkler irrigation system is composed of an underground PVC pipeline system, which brings water from the well into the field. These pipelines are of various sizes, ranging from 3 to 6 inches in diameter. The closer they are to the irrigation plot, the smaller they get. The main pipelines dimensions are 150mm x 11m (6 inches x 37ft) and are made of aluminum. The lateral pipelines dimensions are 75mm x 9m (3 inches x 30ft). Each lateral comes with a sprinkler head. In order to cover the entire irrigated area, 14 main pipelines, 1,200 laterals (15 rows of 80 laterals each) and 1,200 sprinkler heads are used. In the field, the system is set up in 15 rows of laterals, with each row consisting of 80 pieces. The length of the area covered by this system is 720m (80pcs x 9m/pc), and the width is 154m (14pc x 11m/pc). However, the total area irrigated at once, using this sprinkler irrigation system is 12.67 ha or 31.31 acres. The system is moved across the plots, as needed, since 142 ha or 350 acres are irrigated altogether.

A single irrigation event takes 2 to 3 hours, with 2 people working in the field for that amount of time. One person is at the control end of the station and another one in the field checking proper functioning of the sprinklers Installation or removal of the irrigation system takes on average 5 people over 5 hours to install or remove the sprinkler irrigation system. Figure 5.7 shows the layout and components of a typical sprinkler irrigation system used for onion production.



Source: Gokul (2017)

Figure 5.7. Layout and Components of a Typical Sprinkler Irrigation System

The cost of investment associated with a sprinkler irrigation system is detailed in Table 5.22. These costs are based on an irrigated area of 12.67 ha (31.31 acres). The total cost of a sprinkler irrigation system was estimated to be slightly over $3,400/acre. These costs were derived using the producers layout and specification, and using an irrigation system price guideline document, AGDEX 753, developed by CRAAQ (2011). In some cases, information was supplemented through personal communication with Nissim Maman from Aquadrip Inc. The cost of tensiometers was included in the system, even though the surveyed producer did not use this method of soil water level control. It was included in study to conform to studies (those by Rekika, 2014; Jenni et al., 2012) that were used to obtain crop yield, water use, and elecricity use differences used tensiometers to trigger irrigation.

Table 5.22. Cost of Investment for the BMP Technology – Sprinkler Irrigation System for Onion Production

Sprinkler irrigation components	**$/ha**	**$/acre**
Mainline pipelines (150mm x 11m)	$251.42	$101.74
Mainline connectors	$76.24	$30.85
Lateral pipelines (75mm x 9m)	$820.04	$331.84
Lateral connectors	$613.03	$248.07
Sprinkler head and fittings	$1,792.08	$725.19
Sprinkler accessories (i.e., risers, fittings, etc.)	$1,535.07	$621.19
Irrigation Pump (200 HP electrical)	$380.43	$153.95
Water well (75 m x 150mm)	$1,387.06	$561.29
Irrigation reservoir (6,000 m3)	$998.64	$404.11
Installation costs	$81.25	$32.88
Tensiometers (TX-80-WL and TX3, Hortau Inc.)	$503.04	$203.58
Total	**$8,438.30**	**$3,414.68**

5.2.3.1 Financial Benefits and Costs Associated with the BMP

Like the previous financial evaluations, financial performance of a BMP is affected by two major factors: Change in revenue through yield increases and change in the cost of production for onions. Both factors are discussed in this subsection. Onion production costs are presented in Appendix F.

Effect on Yield: Using irrigation in onion production is reported to increase yields over and above that under dryland production. These results have been consistent among various studies. Rekika et al. (2014) measured yield differences associated with three irrigation treatments, which consisted of no irrigation, irrigation during the bulbing stage, and irrigation throughout the growing season. One of their research sites was located in Sherrington and the other one in Naperville (Rekika et al., 2009). For their case study farm, in the 2008 growing season, onion yields under dryland irrigation were 73.5 Mg/ha, while under irrigated conditions (involving irrigation during the bulbing stage) were 78.8 Mg/ha, a 7.21% increase (5.3 Mg/ha or 546 kg/ha). During the 2009 season, the dryland treatment yield was 65.1 Mg/ha, whereas that for the irrigation treatment was 71 Mg/ha, thereby a 9.06% yield increase (5.9 Mg/ha or 607.7 kg/ha) (Rekika et al., 2009).

Jenni et al. (2012) found that irrigation increased total yields by 11% on one site and had no effect on yields on another site due to high precipitation levels. Schock et al. (1998) and Pelter et al. (2004) also evaluated the effects of irrigation on onion yields and found similar results. Also noteworthy in this context is the fact that not all size categories of onions increase uniformly under irrigation. From Rekika et al. (2009) and (2014), one knows that the jumbo (diameter >76mm) category yield increases more under irrigation. This is relevant from an economic standpoint, as this category has on average a higher price than prepack (<45mm), small (45-57mm) and medium (57-76mm) categories.

For evaluating the sprinkler irrigation system's feasibility, following Rekika (2014), a somewhat conservative approach was used which involved the assumption that the yield increase between dryland onion production (baseline scenario) and sprinkler irrigation (study technology) was of only 7.21%.

Onions can be held in storage for up to 4-5 months. Rekika et al. (2009) have reported storage effects on onion yields. Their findings show that irrespective of whether onions are irrigated or not, storage reduces onion weight loss. Such losses are estimated to be between 23% and 25% for non-irrigated onions, and between 16% and 26% for irrigated onions. However, even after storing half the onions produced for 4 months, gross revenues were between 5% and 28% higher for irrigated onions, as compared to non-irrigated onion yields (Rekika et al., 2009). While this effect was not accounted for in the base economic analysis, it was used in the sensitivity analysis to test the robustness of results.

Each season, the surveyed producer grows onions and carrots together. Therefore, the farm budget developed for this case study also includes yield effects on carrots production. A 2012 report on the profitability of vegetables, potatoes and fruits, prepared by Serecon Management Consulting, for the Alberta Agriculture and Rural Development Division (Serecon, 2012), reported carrot yield differences between dryland and irrigated production. Based on this report, under irrigated production, carrots yield increases by 40% when compared to dryland production – from 15 tons/acre to 21 tons/acre (37 tons/ha and 52 tons/ha) (Serecon, 2012). In this study, however, a more conservative estimate of only a 20% yield difference between irrigated and dryland carrots was followed.

Carrots and onions are grown in rotation with lettuce or spinach. Data from CRAAQ (2008) was used to estimate the benefits and costs associated with growing lettuce. These estimates were based on AGDEX 251/821. However labour costs were added to these costs, plus these costs were adjusted to the 2015 reference year. The net revenue for lettuce production was $2,711 per acre (based on variable costs of $19,655 per acre, fixed costs of $1,965 per acre and gross revenue of $24,330 per acre). It was assumed that switching from dryland to irrigation would have no increase on lettuce yields.

Given the inability to collect cost of production data from the producer, secondary data sources, as described above, were used to estimate differences in gross revenues coming from switching from no irrigation to sprinkler irrigation in onions and carrots production. If onions yield increases by 7.21% and carrots yield by 20%, gross revenues for fields under drip irrigation increase by 14% over the baseline, more precisely by $1,268 per acre as shown in Table 5.23.

Effect on Cost of Production: Based on available data for onion production, annual irrigation costs (using sprinkler irrigation) were $101 per acre, including both labour and energy costs. When compared to cost of production under no irrigation, the biggest difference in their respective costs is associated with packing and storing. The $442 /acre increase in costs under sprinkler irrigation over the dryland is due to yield increase. Differences in the cost categories are shown in Table 5.23. Both technologies are similar except for the cost of irrigation, packing and storing. As shown in Figure 5.8, packing and storing, account for over 40% of the total costs of production, followed by cultural practices, which account for over 30% of the costs. Irrigation cost are a small proportion of the total cost.

Economic Desirability Indicators: As noted above three economic indicators were estimated for the BMP and baseline technologies. Results are shown in Table 5.24. On both criteria – NPV and BCR, the study technology (sprinkler irrigation) is a more financially attractive alternative. Under this BMP, the net present value per acre was $9,174, over 7% higher than that under dryland production system. However, the BCR for these technologies is identical (estimated to be 1.10).

Table 5.23. Difference in Cost under the Baseline and BMP Technology for Onion Production, 2015 ($/acre)

Particulars	**Baseline (No Irrigation)**	**BMP (Sprinkler Irrigation)**	**Difference (Baseline-BMP)**
Gross Revenue	$8,895	$10,163	-$1,268
Land Preparation	$793	$793	$0
Cultural Practices	$2,391	$2,391	$0
Irrigation Costs	$0	$101	-$101
Harvesting	$903	$947	-$45
Packing and Storing	$2,911	$3,353	-$442
Variable Costs	$6,997	$7,585	-$588
Fixed Costs	$795	$819	-$24
Total Costs	$7,792	$8,404	-$612
Net Returns	$1,103	$1,759	-$656
Net Returns as % of Gross Returns	12.40%	17.31%	4.90%
Initial Investment Cost	$0	$3,415	-$3,415

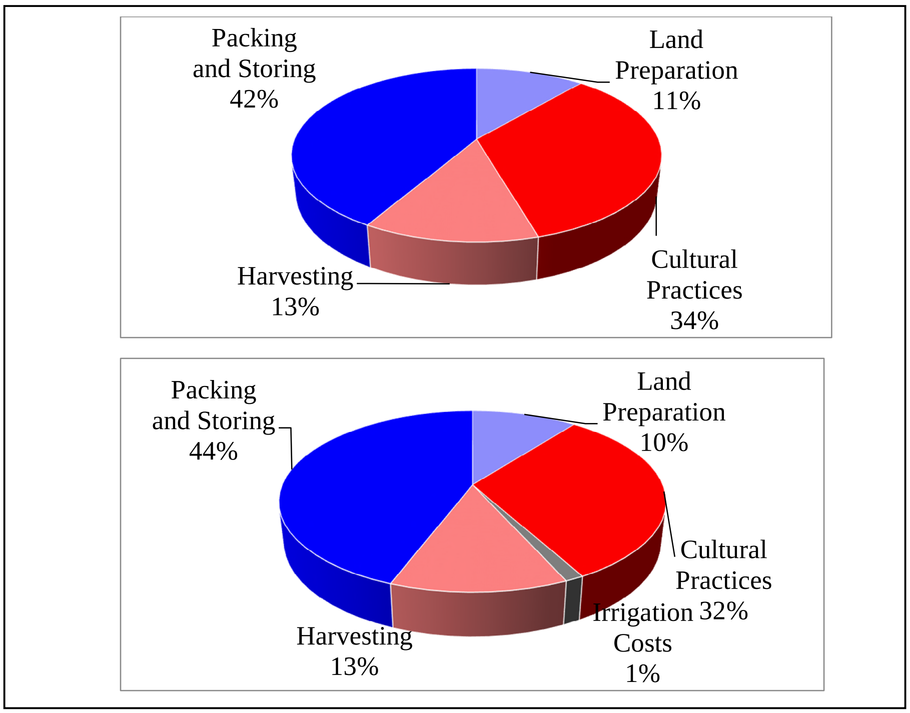


Figure 5.8. Distribution of Total Cost by Major Cost Categories, Baseline technology (Top) and BMP Technology (Bottom) for Onion Production

Table 5.24. Measures of Financial Desirability of Baseline and BMP Technology for Onion Production ($/acre)

Particulars	Baseline (No Irrigation)	BMP (Sprinkler Irrigation)
Net Present Value @ 5%	$8,544	$9,174
Present Value of Benefits	$96,961	$104,453
Present Value of Costs	$88,417	$95,032
Benefit Cost ratio	1.10	1.10

5.2.3.2 Environmental Benefits and Costs

Environmental benefits or damages were measured through change in GHG emissions, as well as through water and energy used. According to Lloyd (2016), there were no statistically significant differences in GHG emissions from the two irrigation treatments. However, anecdotal evidence recorded for years 2012 and 2013 showed that during the 2012 growing season, organic fields under sprinkler irrigation produced 97% less GHG emissions when compared to dryland production (Lloyd, 2016). In the subsequent growing season, onion production under sprinkler irrigation produced 56% more GHG emissions when compared to dryland production. The relative difference between the two treatments, over the two growing seasons with fields under sprinkler irrigation producing 19% less GHG emissions when compared to fields under no irrigation. In the financial evaluation of these two treatments, – differences in GHG emissions were not taken into consideration. However, these results are presented in Table 5.25.

A previous study conducted by Rekika et al. (2014) looked at water use and water use efficiency (ratio between marketable yield and water used – rainfall and irrigation) associated with dryland and sprinkler onion production. Their results show that over the 2008-2009 growing seasons, the water consumption increased by approximately 17% when irrigating onions (irrigation amount was 75mm for 2008 and 60 for 2008), when compared to the dryland production (amount of precipitations for a given growing season was considered the baseline – 420 mm for 2008 and 352 mm for 2009) (Rekika et al., 2014). In addition, water use efficiency was slightly higher under no irrigation (0.17 and 0.18 for 2008 and 2009, respectively), 0.16, and 0.17 for irrigated production. Water use efficiency was calculated as the ratio of marketable yield (Mg/ha) to the amount of water received - irrigation and rainfall (mm).

The only onion category for which the water use efficiency increased under irrigated production was jumbo-sized onions (diameter > 76 mm). When modelling the irrigated production scenario, costs associated with water usage was not incorporated in the budget – the producer is not currently paying for water usage. However, energy costs associated with irrigation are reflected in the costs' calculations.

Table 5.25. Difference in the GHG emissions from No Irrigation (Baseline) and Sprinkler Irrigation Technology (BMP) for Onion Production, 2012-13

GHG	**2012 Growing Season**		**2013 Growing Season**	
	No Irrigation	**Sprinkler Irrigation**	**No Irrigation**	**Sprinkler Irrigation**
N_2O g/m^2	0.11	0.02	0.02	0.06
CH_4 g/m^2	0.03	0.25	0.00	-0.02
CO_2 g/m^2	187	-9.76	224	344
CO_2 -eq g/m^2	222	6.14	231	360
CO_2 -eq t/ha	2.22	0.06	2.31	3.60
CO_2 -eq t/acre	0.90	0.02	0.93	1.46
Relative Difference		-97%		56%

Source: Lloyd (2016)

Other environmental effects mentioned by the surveyed producer are soil erosion reduction, frost protection and general risk of production reduction due to better timing of water availability to the plant, as required throughout the plants' developmental stages. These effects were not accounted for in the economic analysis, due to lack of data.

5.2.3.3 Social Benefits and Costs

Major social impact of the technology was measured in terms of labor requirements, leading to leisure time available to the producer. As expected, when compared to no irrigation, sprinkler irrigation system requires more hired agricultural labour. Based on the discussion with the producer, it takes five people about five hours to set up the irrigation system at the beginning of the growing season, and the same requirements to remove the system from the files, at the end of the season. During the growing season, the estimated time required to irrigate is of three hours for two people per irrigation event, to irrigate about 12 ha (30 acres).

Related to the farmer's leisure time, the question posed was -- Are there any farm owner lifestyle changes involved when moving from no irrigation to sprinkler irrigation? Based on our anecdotal evidence, from the case study farm, there is an increase in time spent by the farm owner or manager related to decision-making.

5.2.3.4 Onion Production Main Analysis Summary

Summary findings for onion production under no irrigation and sprinkler irrigation indicate that from a purely economic standpoint, adopting a sprinkler irrigation system increases NPV by over 7%. In addition, the benefit-cost ratio remains greater than the break-even mark. While not quantitatively assessed, reduction in production risks – water availability timing, and crop frost protection, should also be considered as potential positive effects of sprinkler irrigation adoption. Beyond the economic benefits, fields with irrigated onions show a decrease in GHG emissions. Furthermore, the producer also mentioned a reduction in soil erosion associated with irrigation of the crop. Adopting irrigation in onion production has some negative effects, such as water use efficiency decrease, increase of energy use, and reduction of leisure time for the producer. Results of this case study are summarized in Table 5.26.

Table 5.26. Summary of Baseline and BMP Technologies for Onion Production

Indicator	**Baseline (No Irrigation)**	**BMP (Sprinkler Irrigation)**	**Difference (BMP – Baseline)**
Economic (NPV) ($/acre)	$8,544	$9,174	Positive increase
Economic (BCR) ($/acre)	1.10	1.10	Positive no change
GHG Emissions (CO_2-eq kg/ha)	2,263	1,832	
Water Use Efficiency	0.17-0.18	0.16-0.17	Negative reduction
Energy Use	0	+17%	Negative increase
Social Impact (leisure time)	+	-	Negative reduction

5.2.3.5 Sensitivity Analysis for Onion Production

Since several factors could affect the relative economics of irrigation and dryland production systems, a sensitivity analysis of financial indicators was undertaken. The factors involved in this analysis were weight loss in storage leading to yield obtained, product prices, discount rates, and initial capital costs.

Changes in Crop Yield: After storage, irrigated onions have been shown to reduce their weight by anywhere between 16% and 26% (Rekika et al., 2009). For non-irrigated onions, storage reduces their weight between 23% and 24%. In this sensitivity analysis, onion yields were modified based on these losses. Given that carrot storage loss was already accounted for in the original cost of production calculation (20% loss was assumed in accordance with CRRAQ's AGDEX 258/821), only onion storage losses were accounted for in the sensitivity analysis. In this analysis, a 22.6% onion yield reduction for the baseline scenario, and 15.9% and 25.7% reduction for the irrigated onions, followed by a 23.6% reduction in non-irrigated onions. Results of the analysis are presented in Table 5.27.

Table 5.27. Comparison of Baseline and BMP Technology at Different Onion Yields ($/acre)

	Baseline (No Irrigation		**BMP (Sprinkler Irrigation)**
	-22.6%	**-15.9%**	**-25.7%**
Net Present Value @ 5%	$6,113	$6,365	$5,314
Present Value of Benefits	$93,407	$100,138	$98,616
Present Value of Costs	$87,294	$93,773	$93,302
Benefit- Cost Ratio	1.07	1.07	1.06
NPV difference		$252	-$799
NPV change from baseline		4.13%	-13.07%
	Baseline		**BMP**
	-23.6%	**-15.9%**	**-25.7%**
Net Present Value @ 5%	$5,996	$6,365	$5,314
Present Value of Benefits	$93,237	$100,138	$98,616
Present Value of Costs	$87,241	$93,773	$93,302
Benefit- Cost Ratio	1.07	1.07	1.06
NPV difference		$369	-$681
NPV change from baseline		6.16%	-11.37%

Results show that sprinkler irrigation continues to be more profitable compared to dryland production, if only 16% of onion yields are reduced during storage. However, when irrigated onions yield drops by 25.7%, dryland production performs better from an economic standpoint than irrigated production. Under these conditions, the sprinkler irrigation NPV is lower by 11%

and 13%, when compared to the baseline benchmarks of 23.6% and 22.6% loss, respectively, under no irrigation scenario.

Change in crop price: In the base economic analysis for onion production, an average price for both onions and carrots production, in accordance with CRAAQ (2008), was used. For the second sensitivity analysis, a 5%, 9% and 14% price decrease were assumed. Sprinkler irrigation becomes less attractive financially if crop prices drop by 14% (Table 5.28).

Table 5.28. Comparison of Baseline and BMP Technology at Different Onion and Carrot Prices ($/acre)

Baseline (No Irrigation)				
	0%	-5%	-9%	-14%
Net Present Value @ 5%	$8,544	$6,467	$4,661	$2,167
Present Value of Benefits	$96,961	$94,849	$93,043	$90,585
Present Value of Costs	$88,417	$88,382	$88,382	$88,418
Benefit- Cost Ratio	1.10	1.07	1.05	1.02
BMP (Sprinkler Irrigation)				
	0%	-5%	-9%	-14%
Net Present Value @ 5%	$9,174	$6,776	$4,714	$1,866
Present Value of Benefits	$104,453	$101,808	$99,746	$96,898
Present Value of Costs	$95,032	$95,032	$95,032	$95,032
Benefit- Cost Ratio	1.10	1.07	1.05	1.02
NPV increase over Baseline	7.37%	4.78%	1.14%	-13.91%

Change in discount rate: Increasing the discount rate from 5% to 10% and then to 15%, changed the relative difference in the profitability of the two scenarios. Discounting future costs and benefits more heavily, slight increases in the gap between their respective NPVs were found, with dryland irrigation having higher net returns. At a discount of 5%, the profitability of onion/carrot production under sprinkler irrigation, as assessed through by NPV, is approximately 7% higher when compared to dryland production. At discount rates of 10% and 15%, the decrease over the baseline scenario is nearly 5% and over 16% respectively (Table 5.29).

Change in investment cost: To ensure robustness of results, NPV values for sprinkler irrigation at a 5%, 10% and 15% increase in the initial cost of the system were calculated. Compared to dryland, sprinkler irrigation remains more profitable if the increase in the total cost of the sprinkler system is of 17%, as shown in Table 5.30. With an increase of 32 or 46% in the capital cost of irrigation system, production under this technology has an NPV of approximately 4% and 9% lower than dryland production.

Table 5.29. Comparison of Baseline and BMP Technology for Onion Production at Different Discount Rates ($/acre)

	5%	10%	15%
Baseline (No Irrigation)			
Net Present Value	$8,544	$6,279	$4,848
Present Value of Benefits	$96,961	$71,023	$54,568
Present Value of Costs	$88,418	$64,744	$49,720
Benefit Cost ratio	1.10	1.10	1.10
BMP (Sprinkler Irrigation)			
	5%	10%	15%
Net Present Value	$9,174	$5,982	$4,091
Present Value of Benefits	$104,207	$76,313	$58,710
Present Value of Costs	$95,032	$70,331	$54,619
Benefit- Cost Ratio	1.10	1.09	1.07
NPV change over Baseline	7.38%	-4.73%	-15.62%

Table 5.30. Comparison of Baseline and BMP Technology for Onion Production at Different Capital Investment Costs ($/acre)

	Baseline (No Irrigation)	**BMP (Sprinkler Irrigation)**			
		0%	17%	32%	46%
Net Present Value @ 5%	$8,544	$9,174	$8,663	$8,212	$7,792
Present Value of Benefits	$96,961	$104,207	$104,248	$104,285	$104,320
Present Value of Costs	$88,417	$95,032	$95,585	$96,073	$96,528
Benefit- Cost Ratio	1.10	1.1	1.09	1.09	1.08
NPV increase over Baseline ($)		$630	$119	-$332	-$752
NPV increase over Baseline (%)		7.37%	1.40%	-3.88%	-8.81%

5.3 SUMMARY RESULTS AND DISCUSSION

With increased evidence of changing climatic conditions, on farm mitigation or adaptation strategies play an important role in reducing GHG emissions and reduce producers' vulnerability to effects of climate change. Across Canada, efforts have been made to develop and implement improved technologies and management practices (called BMPs) that could be implemented with government help (such as through cost-share programs) or without them. Such BMPs are intended to minimize their negative impacts of agricultural production on the environment. For farmers to be favourably disposed to their adoption, financial gains are important. Where financial gains to farmers are not enough, their implementation at the farm level would invariably require governmental support, if benefits from such adoption to the society also exist.

Farmers' decision to adopt or not a certain BMP relies on multiple factors. However, one of the most important factors is the financial desirability of the investment. Financial desirability of various BMPs in the context of tomato, cranberry and onion in Ontario and Québec have not been reported in the available literature. It is therefore essential to understand the financial effects of adopting these BMPs. In this study, quantification and evaluation of BMPs was done from a private accounting stance – through a partial budget analysis. In the next section, results of the farm level evaluation of the proposed BMPs are summarized.

5.3.1 Results for Financial Desirability of BMP for Tomato Production

For tomato production, focus was on 1,000 acres (400 ha) tomato farm, located in Southern Ontario, where the effects of irrigating using surface and subsurface drip irrigation were compared. Only 110 acres of this area were allocated to tomato production, half of which was under surface drip irrigation, while the other half under subsurface drip irrigation.

Previous studies have shown yield increase of at least 5% in tomatoes under subsurface drip irrigation, when compared to those under surface drip irrigation (Tan and Reynold, 2003). However, the grower whose farm was selected for this evaluation mentioned that no yield differences were observed between the two irrigation systems; hence, the no yield increase assumption was made for the base simulation. The grower also used the same amount of water, energy and fertilizers for both fields under surface and subsurface drip irrigation, in spite of the fact that other studies have indicated the BMP improves both nutrient use efficiency and improved water use efficiency (Tan et al., 2003; Martinez and Reca, 2014). Although GHG emissions were estimated to be 17% less under subsurface, they were not statistically significant; the amount of emissions were 1.29 $CO_{2\text{-eq}}$ t/ha less annually under subsurface drip irrigation (Edwards, 2014).

This study showed that subsurface drip irrigation increased net returns by 46% over and above that from surface drip irrigation system. The only difference in the cost of production was associated with irrigation. There was a 12.5% decrease for subsurface drip irrigation (BMP) when compared to surface drip irrigation (Baseline), resulting in total cost of production to decrease from \$3,846 to \$3,346 per acre. Furthermore, other indicators, like NPV calculated over 15 years, increased by over 20%, from \$5,450 to \$6,564 under subsurface drip irrigation. The benefit-cost ratio for each of these practices was estimated at 1.22 and 1.28 (for surface and subsurface drip irrigation, respectively). Higher BCR for the sub-surface drip irrigation BMP was obtained even though the cost of investment for the surface drip irrigation was lower (\$1,178 per acre vs. subsurface drip irrigation cost of \$1,298 per acre) by 10%. Lower cost of irrigation for the subsurface drip irrigation BMP resulted in these results.

Beyond financial desirability of the BMP, this study also found that spatial variability of farm soil leveling, and soil texture were important factors influencing the growers' decisions to adopt the study BMP**.** The BMP adoption took place in stages: small trial area at first, depth of installation varied, and years of the system left in place, until the optimum was found. A reliable source of water supply was crucial to the decision to adopt the BMP. The grower also mentioned that the new BMP increased his time spent taking decisions but reduced hired labor requirements.

These findings were obtained under a set of assumptions related to tomato prices, discount rates, loan considerations, and farm size, among other parameters. To ensure the robustness of this farm level analysis, and expand the applicability of results, sensitivity analyses were undertaken. This allowed me to understand variations in profitability for the baseline and alternative BMPs. Results indicated that the BMP remains more profitable than the Baseline technology used on the farm. Even with tomato prices dropping by 2, 6 or 7% the subsurface drip irrigation outperformed the baseline method of irrigation. Similar results were obtained for different discount rates (selected at 10% and 15%), at an increased cost of investment of up to 45%, or whether the farmer took on a loan or not. Taking opportunity costs into consideration – instead of investing in a new technology invest in CIGs with an annual return rate of 2.19%, diminishes slightly the profitability of investment, however the impact is small, and the alternative technology still outperforms the baseline one. Varying the size of the farm and the area under tomato cultivation showed differences in capital cost of investment and NPV on farms of different sizes. The NPV and BCR for smaller and average tomato processing farms in the region (25 hectares in farm size and 12 ha under tomato production) were estimated with results being proportionally similar between the two BMP

5.3.2 Results of Financial Desirability of BMP for Cranberry Production

In the second farm level analysis, the focus was on 1,400 acres (567 ha) cranberry farm, located in Saint-Louis-de-Blandford, Québec. Using this case study, the effects of two water management systems were evaluated. The baseline scenario reflected the effects of growing cranberries under a relatively wet water management strategy, where the grower irrigated the crop twice every other day, without using a device to assess the water table level. Irrigation was done using sprinkler irrigation, together with a system of subsurface drains and control structures around cranberry beds. Under the alternative scenario, which represented a drier water table management strategy, tensiometers were used to assess water needs, and subsurface drains are installed closer to one another. On average 1,065 acres (400 ha) were allocated to cranberry production, with only 20% of this area under the project BMP. The main water source for irrigation purposes is an on-farm reservoir fed by rain or by water pumped from the Becancour River.

Using a drier water management system (BMP) in cranberry production was assumed to increase yields by 16% compared to 35,000 kg/ha obtained under a wetter treatment (Baseline). A reduction of 74% in water use was assumed under the BMP scenario, compared to the baseline. Irrigation costs under the baseline scenario were estimated to be $728/acre ($1,800/ha). These costs were reduced to $591/acre ($1,461/ha) under the BMP scenario. In addition, according to Grant (2014), GHG emissions were 3% less under a drier treatment (BMP) but were not found to be statistically significant.

The study findings show that the drier water management scenario (BMP) increased farm net returns by 54%. This was a result of changes in both revenues and irrigation costs. The dry water management scenario had an increase of 16% in revenue over the baseline treatment, and a 19% decrease in costs, relative to the baseline scenario. Furthermore, other indicators, like NPV calculated over 20 years, increased by over 54%, from $25,700 to $39,223 per acre under the wet water management system scenario, in comparison with the baseline. The benefit-cost ratios were 1.42 and 1.64 for dry and wet water management scenarios, respectively. There is a difference in terms of costs of investment between the two systems, with the baseline system cheaper at $2,257 per acre, relative to the alternative system at $2,949 per acre. This is about 31% higher cost under the wet water management system.

Similar to the financial desirability of BMP for tomato production, the above findings were also estimated under a given set of assumptions related to cranberry prices, discount rates, loan considerations, and farm size, among others. Sensitivity analysis results indicated that irrigating cranberries using a drier water management system was more profitable than a wet treatment, irrespective of the changes in the above set of assumptions. Even with cranberry prices dropping by up to 20%, the wet water management system outperformed the baseline system. Similar results were obtained for different discount rates (10% and 15%), at an increased cost of investment of up to 20%, or whether the farmer took on a loan or not. Varying the size of the farm and the area under cranberry cultivation suggested that costs of investment and NPV on farms of different sizes varies proportionately.

5.3.3 Results of Financial Desirability of BMP for Onion Production

In the last farm level analysis of this study, the focus was on 1,500 acres (607 ha) onion producing farm, located in Saint-Patrice-de Sherrington, in Montérégie, Québec. In this case study, the effect of two water management systems were compared. The baseline scenario was that of no irrigation and no water table management, and the BMP scenario was sprinkler irrigation system together with the use of a tensiometer to help determine crop water needs. Approximately 350 acres (142 ha) were allocated to onion production. Onions and carrots were intercropped in a two-year crop rotation with lettuce and spinach. The farm section dedicated to onion production is done on highly decomposed organic matter soil. Water sources for irrigation were mixture of some water coming from an on-farm well, and more recently from an on-farm reservoir. The cost of investment for the sprinkler irrigation system was of $3,415 per acre ($8,438 per ha).

To compare the two scenarios, a yield increase of 7% for onions grown under the BMP scenario by comparison to dryland onion production (baseline scenario) was assumed. Onions are grown in rotation with carrots and lettuce. For these two crops, different yield effects were assumed. For carrots grown under the BMP scenario, a 20% increase was assumed, compared to the baseline. However, for lettuce production no yield differences were assumed between the two scenarios. The GHG emissions were 19% less under sprinkler irrigation, although not statistically significant. These emissions were 1.83 $CO_{2\text{-eq}}$ t/ha less annually under sprinkler irrigation (Lloyd, 2016). Other environmental effects mentioned by the surveyed producer were soil erosion reduction, frost protection and general risk of production reduction due to better timing of water availability to the plant, as required throughout the plants' development stages. These effects were not valued and included in the financial analysis.

The study showed that sprinkler irrigation, increased net returns by 59%. Differences in the cost of production between the two scenarios were associated with irrigation, packing and storage. The NPV calculated over a 15-year period increased by over 7%, from $8,544 to $9,174 per acre under sprinkler irrigation, compared to no irrigation.

These findings were also obtained under certain assumptions related to onion and carrot prices, their yields, discount rates, loan considerations, and farm size variation. To test for the robustness of this farm level analysis, sensitivity analyses were used. These results indicated that sprinkler irrigation continues to be a more profitable option for onion (and carrot) production compared to dryland production. However, since onions are stored over a period, they suffer a loss of weight. To account for this, onion yields were reduced by16% of onion yields. This still resulted in a better financial performance of irrigation over dryland. However, when irrigated onions yield was reduced by 25.7%, dryland production performed better than irrigated production. Furthermore, sprinkler irrigation became less economically desirable if crop prices were to drop by 14% relative to the baseline scenario. Similar results were obtained for different discount rates. At a discount of 5%, the profitability of onion/carrot production under sprinkler irrigation as assessed by NPV was approximately 7% higher than that under dryland production. However, when discount rates were increased to 10% and 15%, the BMP scenario is less desirable from a financial standpoint, with an NPV decrease of nearly 5% and over 16% when compared to the baseline scenario.

5.3.4 Farm Analysis Discussion

This study findings show that for all three commodities, the proposed improved water management BMP financially outperformed the baseline technology. The robustness of these results were reaffirmed through sensitivity analyses, even though some exceptions were encountered in the case of the BMP for the onion farm.

In terms of environmental effects, it is more difficult to make more certain conclusions. This is because, as noted above, most of these data were obtained from secondary sources; they were collected over a short period of time; and in some cases conducted on different farms, albeit in the same area. One of the environmental effects of interest was GHG emission levels coming from the different BMPs. These data were collected only over two growing seasons and showed large variability over the two periods. This resulted in a lack of statistical significance in the differences between each of the two water management systems. Even though previous findings from Edwards (2014), Grant (2014) and Lloyd (2016), have shown that on average, over two growing seasons the proposed BMPs produced less GHG emissions, these results need to be further verified. This is also the case for other environmental effects related to water, energy and nutrients use efficiency. Several studies have shown that farming using the proposed BMPs has the potential to reduce water and energy use and increase the efficiency of nutrient use.

In terms of social effects, the results were mixed, with some BMPs increasing hired labor needs, while others did not, however these effects were accounted for in the financial analysis. Furthermore, all proposed BMPs required more involvement in decision making from senior management staff or by the farmer, which could potentially reduce the availability of spare time for leisure.

This enterprise-based analysis of three case study farms involved practical solutions, which allowed the comparison of a status quo water management system to an alternative system proposed to improve water management. The case studies could be called a practical solution to the previous approaches that involved surveying a large sample of farms in each one of the regions. Data for this approach were more time and resource consuming than this study approach. Furthermore, the study approach permitted an in-depth understanding of costs and benefits associated with adoption.

While the case study is one account, which does not allow for wide and reliable generalization of results, it does serve as good guide to future investigations in an ongoing longer-term research project (such as the AGGP). These case studies can help inform the development of representative farm models for the studied commodities within the study area. This research can also serve as a building block for future studies – since key elements that are important in the adoption of irrigation technologies and practice were identified. Thornley and France (2007) mention that deterministic models could be a useful first step in performing analyses, and that once developed, these models can be assessed to determine the need for additional stochastic modelling. Although based on this study, even though broad generalization of results to the entire population of tomato, cranberry and onion growers in Ontario and Québec is not possible, this research provides transferable knowledge to other farms in these regions, which have similar cultural practices and biophysical conditions**.** Our results also show that even on smaller farms the proposed BMPs can be profitable**.**

Farm analyses were conducted using deterministic models, which neither account for risks and uncertainties related to variation in market prices for inputs or outputs, nor variability in climatic conditions. Both of these factors are highly relevant to agricultural production systems. Modeling the impact of changes to farm economics using a deterministic model can eventually result in an overestimation of the effects of the change on the farm's economics (Robertson et al., 2012). Even though the effect of influential parameters on profitability of investment through sensitivity analyses was tested, these factors were looked at in a disaggregate manner. A producer could face many of these factors at once. While findings are robust, it is important to consider limitations, when using these findings to inform farmers, academics, or policy related decisions.

CHAPTER 6. ADOPTION OF BENEFICIAL MANAGEMENT PRACTICES RESULTS

6.1 INTRODUCTION

Farmers from Southern Québec and Ontario were asked questions related to adoption of BMPs, which included their perceptions vis-à-vis proposed improved practices, their attitudes towards environmental stewardship, and farming goals and motivations. Do these characteristics affect adoption of a BMP? This question is addressed in this Section.

6.2 CHARACTERISTICS OF PRODUCERS AND FARMS

There were 70 growers who completed the survey, of which 39 were tomato growers (56% of total who responded), 19 were cranberry growers (making 27% of the total respondents) and the remaining 12 were onion farmers (constituting 17% of the total respondents). In Appendix G absolute and relative frequencies of respondents for all study variables are summarized.

The majority of respondents (56%) in the survey were of working age – between 35 and 54 years old. In terms of education levels attained, most respondents had either a technical (34%) or a bachelor’s degree (23%). Over 54% of the growers in the sample had over 20 years of farming experience and earned most of their income from farming (as 80% of respondents earned 75% or more of their household income from farming). More details on respondents’ characteristics are provided in Table 6.1.

Respondents were asked about membership in various farm organizations. Predominantly farmers mentioned that they belong to one organization (44%), although there were a few who were a member of multiple farming groups (26%). Only 30% of participants indicated no affiliation with an organization. Most farmers interviewed had an Environmental Farm Plan (91%) in place, which in Ontario is a mandatory condition for eligibility for participating in the BMP cost-share program. Only 40% of the farmers had previously adopted a BMP. When asked about their farming goals, most respondents (53%) indicated that their goals represented a mixture of financial and non-financial goals (i.e., lifestyle).

Table 6.1. Demographic and Personal Characteristics of Respondents (N = 70)

Respondent Characteristics		**Frequency (N)**	**Percent of total respondents (%)**
Age			
	18 to 24	4	5.71%
	25 to 34	9	12.86%
	35 to 44	13	18.57%
	45 to 54	26	37.14%
	55 to 64	12	17.14%
	65 and over	6	8.57%
Education			
	High School	9	12.86%
	College	7	10.00%
	Technical Degree	24	34.29%
	Bachelor's degree	16	22.86%
	Graduate or Professional Degree	14	20.00%
Household Income from Farming			
	No income from farming	3	4.29%
	25% of income from farming	4	5.71%
	50% of income from farming	7	10.00%
	75% of income from farming	22	31.43%
	100% of income from farming	34	48.57%
Farming Experience			
	Under 10 years	15	21.43%
	Between 10 and 20 years	17	24.29%
	Between 21 and 30 years	17	24.29%
	Over 30 years	21	30.00%

Agricultural producers in the sample, operated farms of various sizes. Slightly over 44% have farms under 500 acres (200 ha), while nearly 19% of growers have farms between 500 and 1,000 acres (400 ha), and 36% of the sample farms over 1,000 acres (Table 6.2). On average, growers allocate 44% (SD = 34%) of their land to study crops – tomato, cranberry or onion production, with a median value of 25%. However, in absolute number of acres, the area allocated to either one of the crops was under 100 acres (40 ha) for approximately 33% of growers, between 100 and 200 acres (80 ha) for 47% of growers and over 200 acres for 20% of them. Over 84% of respondents owned 50% or more of their land. In terms of annual gross sales, nearly 76% of growers have sales of half a million dollars and over. Crop sales accounted for over 50% of sales for 41% of the respondents, and somewhere between 25% and 50% of sales for 36% of the respondents.

Table 6.2. Farm Related Characteristics of Sample Respondents (N = 70)

Farm Characteristics		**Frequency (N)**	**Percent (%)**
Farm Size			
	Under 500 acres	31	44.29%
	500 to 1,000 acres	13	18.57%
	Over 1,000 acres	25	35.71%
Crop Size			
	Under 100 acres	23	32.86%
	100 to 200 acres	33	47.14%
	200 acres and over	14	20.00%
Owned Land			
	Under 50%	11	15.71%
	50% to 75%	23	32.86%
	Over 75%	36	51.43%
Average Annual Gross Sales			
	Less than $99,000	7	10.00%
	$100,000 to $249,000	4	5.71%
	$250,000 to $499,000	6	8.57%
	$500,000 to $1,000,000	17	24.29%
	Over $1,000,000	36	51.43%
Percentage Crop Sales Annually			
	Under 25%	14	20.00%
	Between 25% and 50%	25	35.71%
	Over 50%	29	41.43%

The seventy agricultural producers surveyed were classified into adopters or non-adopters based on their response to the question related to BMP adoption. The two groups were equal with 50% of the growers interested in adopting the proposed BMP and 50% not interested. Results were different within different farm groups. Majority of onion growers were in favor of adopting the proposed BMPs (*66.7% N = 12*), like cranberry producers who were also predominately in favor of adopting subirrigation (*89.5%, N = 19*), whereas tomato growers were not interested in adopting a subsurface drip irrigation system (*82.9%, N = 39*).

Some of the factors that might affect the responses of producers for adoption of the BMP were also different between the two groups – adopters and non-adopters. The proportion of adopters with higher education levels attained was higher and statistically significant than that for the non-adopters. The statistically significant difference in proportions was assessed by using the Fisher's exact test, p = .032. There was a statistically significant difference in terms of adoption within the three groups of farmers surveyed (χ^2 (2) = 22.43, p < 0.01). This difference was more prominent between the tomato and cranberry growers' groups – with cranberry growers predominately interested in adoption and tomato producers not interested. No statistically significant difference between these two groups existed in terms of age of respondents (χ^2 (2) = 1.61, p > 0.05). Based on the study sample, past behavior (having adopted a BMP in the past) was not found to be associated with future adoption, as assessed by Fischer's exact test, with was not statistically significant (*p = .81*). Adopters and non-adopters, however, were statistically different in terms of farming goals, with adopters having predominately financial goals, whereas non-adopters had other goals as well, beyond the financial ones (*p < 0.05*). The chi-square test, together with Fischer's exact test are described in Appendix H. In addition, in this appendix, results of the chi-square test of homogeneity are summarized, for all variables of interest.

A Mann-Whitney U test was run to determine if there were differences in farming experience between adopters and non-adopters. Distributions of farming experience for adopters and non-adopters were similar, as assessed by visual inspection and as well as by using the Levene's Test of Homogeneity. The significance of Levene's test is over 0.05, which suggests that the assumption of equal variance in each of these groups holds. Mean farming experience was statistically significantly higher in non-adopters than in adopters (U = 326, z = -3.37, p = 0.01). In other words, adopters had less farming experience than non-adopters did. These tests and their results are described in detail in Appendix I.

There was no statistically significant difference between adopters and non-adopters with regard to percentage of income coming from farm activity (U = 589, z = -0.29, p = 0.77). The difference between farm size across the two groups was statistically significant, with non-adopters managing larger farms than adopters do (U = 142.5, z = 1.96, p = 0.05). Adopters have significantly higher shares of sales coming from the study compared to non-adopters (U = 414, z = -2.35, p = 0.02). Land ownership was also statistically different between adopters and non-adopters, with adopters having a higher share of land owned (U = 402.5, z = -2.51, p = 0.01) (additional details in Appendix I).

In summary, respondents willing to adopt the proposed BMP, referred to as adopters, are different from non-adopters in regard to education, farming goals, farm size, share of sales coming from their tomato, cranberry or onion enterprises, share of owned land and farming experience. When compared to non-adopters, adopters had a statistically significant higher level of education attained, less farming experience, and financial farming goals. In addition to this, adopters also had smaller farms, a higher share of sales coming from the study crops, and owned a higher share of the land, relative to non-adopters.

6.3 PRODUCERS' PERCEPTIONS OF BMP CHARACTERISTICS

Respondents were asked if they would adopt a given BMP to be used in their production. The proposed BMPs that respondents were asked questions about were subsurface irrigation in tomato production, subirrigation in cranberry production and triggering of irrigation using tensiometers in onion production. From the 70 completed responses, there was an equal split between farmers who were in favor of adoption, and those who were not.

Farmers were also asked about their perceptions related to characteristics of BMPs together with general attitudes towards the environment and their responsibility in protecting it. In the following section, answers of the two groups – adopters and non-adopters, are presented.

Adopters and non-adopters alike, predominately perceived the proposed BMPs, as profitable (80% of respondents, N = 70) but expensive (76%), as having the capacity to reduce water use in their operations (74%), and capable to improve crop yields (73%). Furthermore, approximately 57% of respondents perceived the BMPs as a better alternative than the practice or technology currently used on their farm. The same percentage also thought that the proposed BMPs, if adopted, would reduce production risks.

Respondents were also asked to indicate if they perceived the adoption of the BMPs as providing benefits to the local community and to the society at large. Most farmers indicated that in the context of their farm they neither agree nor disagree that this would be the motivation for adoption (in other words, they selected the neutral answer). This response could indicate uncertainty related to the effects of the BMP on the local community or on society at large, or that the BMPs are considered to have no effect. Figure 6.1 summarizes these results.

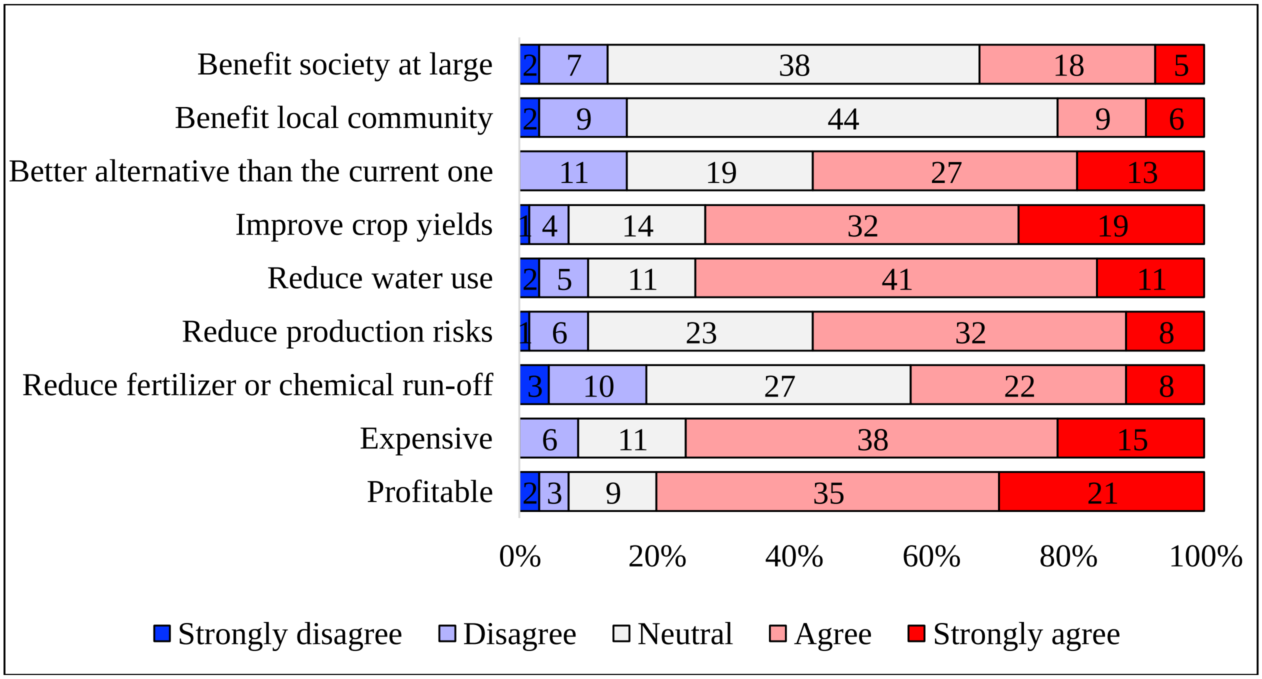


Figure 6.1. Respondents' Perception related to BMP Characteristics (N = 70)

Disaggregating these results by adopters and non-adopters, several differences can be observed, as shown in Figure 6.2. In the subsections below, adopters' perceptions of BMP characteristics are first described, followed by non-adopters' views. The next subsection assesses the difference between adopters and non-adopters concerning perceptions of BMP characteristics.

6.3.1 Perception of BMP Characteristics by Adopters

A total of 35 producers in the survey were categorized as adopters. A large percentage (94%) of the respondents willing to adopt the proposed BMP, perceived the proposed BMPs as being profitable in the context of their farm. Furthermore, among the 32 respondents, which provided answers to this question, 88% agreed or strongly agreed that the proposed system would be a better alternative than the current technology or practice used on the farm.

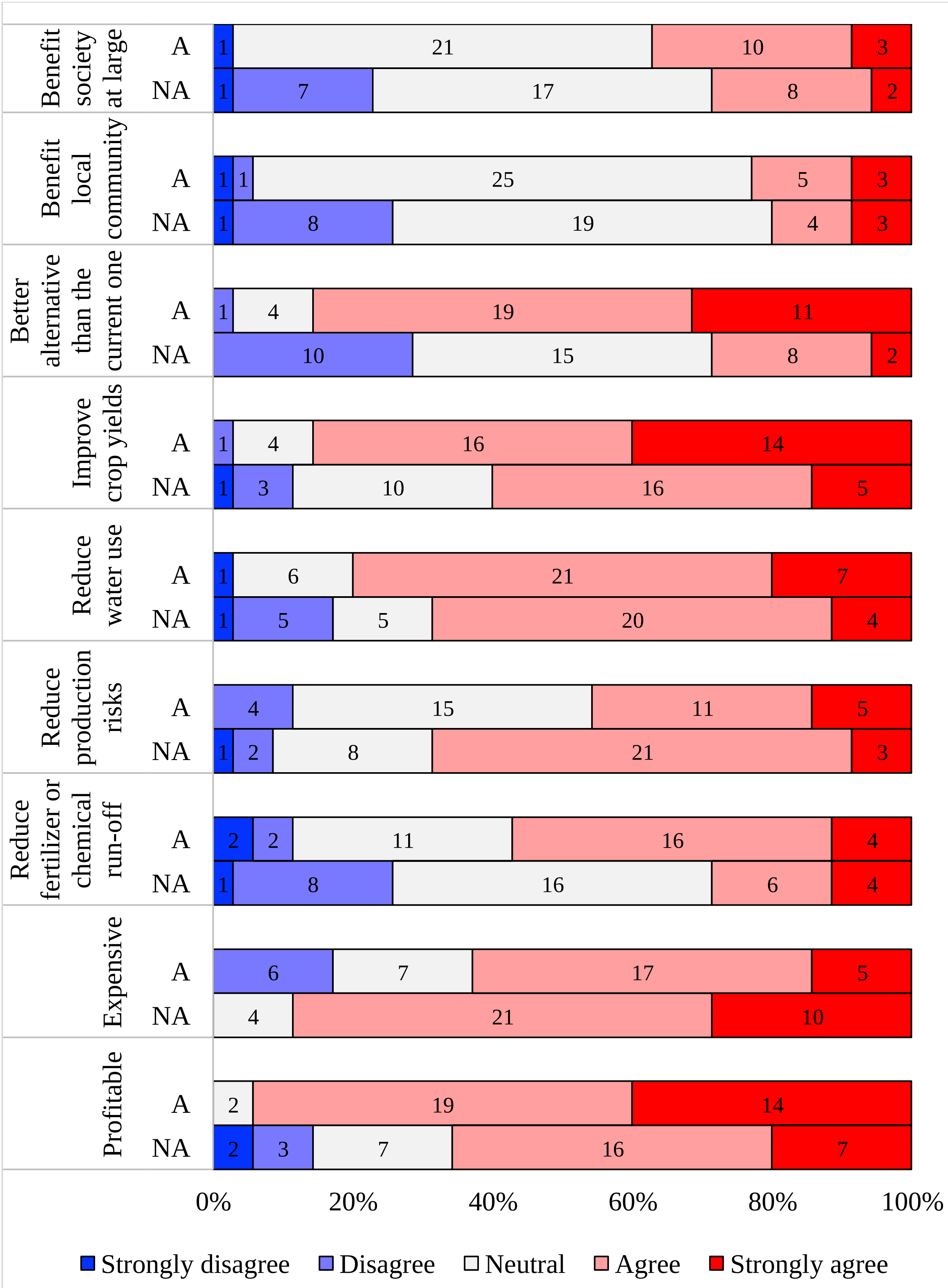


Figure 6.2. Respondents’ Perception related to BMP Characteristics Grouped by Adopters (A) and Non-Adopters (NA) (N = 70)

In addition to these perceived benefits, the majority of respondents also thought that the proposed BMPs would increase crop yields and reduce water use. Most respondents also thought the proposed BMP was expensive. Results also indicate that there might be some uncertainly related to the proposed BMPs potential to benefit the local community and society at large. Majority of producers indicated that they neither agree nor disagree with the statements that the adoption of the BMP could provide benefits to the local community and to society at large. Respondents' were asked the question: "State the level to which you agree or disagree with the following statements. In the context of your farm the improved water management system could the BMP be profitable (or other characteristic)". Responses received for these questions are summarized in Figures 6.3 and 6.4.

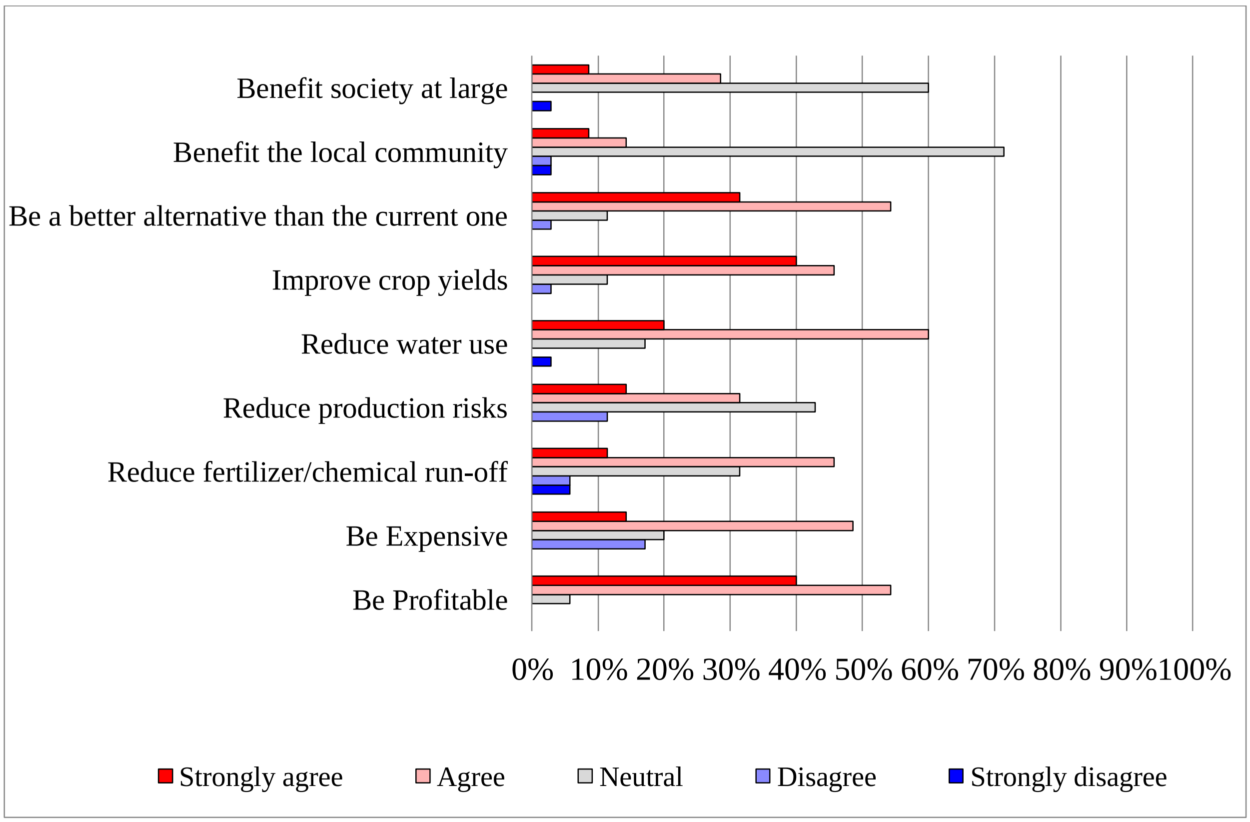


Figure 6.3. Adopters' Perception of the BMPs (*N = 32*)

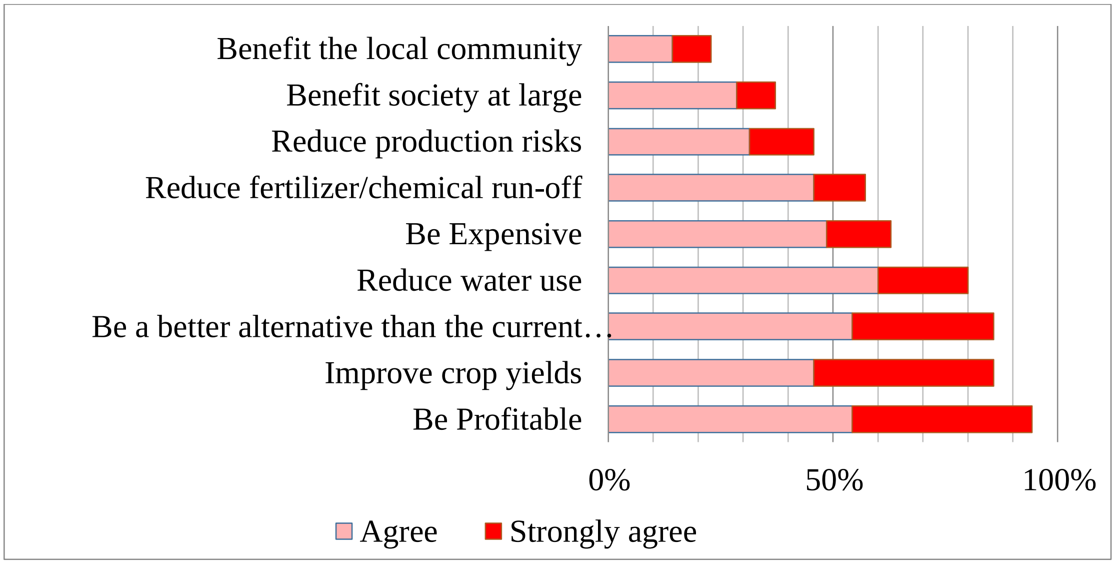


Figure 6.4. Adopters' Perception of the BMPs *(N = 32)*

6.3.2 Perception of BMP Characteristics by Non-Adopters

A total of 35 producers in the survey indicated to be non-adopters. A large proportion of these producers (87% of the total non-adopters) perceived the proposed BMPs as being expensive in the context of their farm. However, of the total of 35 respondents, 65% agreed or strongly agreed that the proposed system would reduce water use and production risks. In contrast to these perceived benefits, only 32% of respondents thought that the proposed BMPs would be a better alternative than the practice they currently use on their farm. Respondents' answers to the question: "State the level to which you agree or disagree with the following statements. In the context of your farm the improved water management system could be profitable (or similar other characteristic): …" are summarized in Figures 6.5 and 6.6.

6.3.3 Perception of BMP Characteristics – Differences

In order to assess differences between adopters and non-adopters a Chi-Square Test of Homogeneity was used. This test was used to determine the existence of a statistically significant difference between the binomial proportions of three independent groups on a dichotomous dependent variable. Whenever the Chi-Square Test of Homogeneity sample size requirements were not met, Fisher's Exact Test was used instead (these tests are further explained in Appendix H). There were statistically significant differences between adopters and non-adopters as related to their perception of the BMPs performance in the context of their farms. Some of the perceptions on which they did differ included whether they perceived it as expensive or not, or a better alternative, having the potential to reduce fertilizer or chemical run-offs. These results are presented in detail in Appendix J.

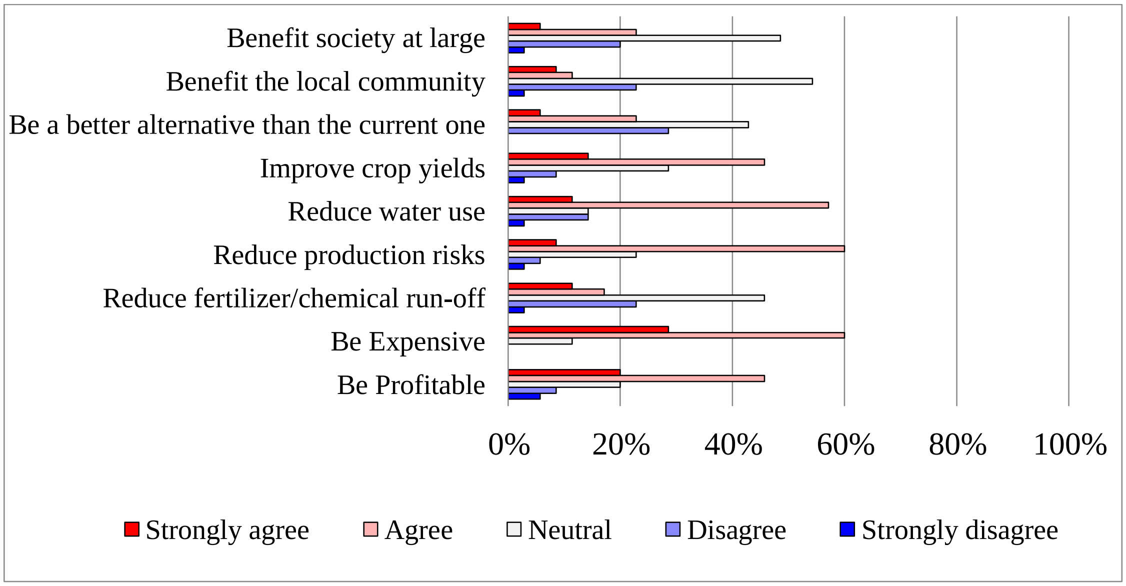


Figure 6.5. Non-adopters' Perception of the BMPs *(N = 35)*

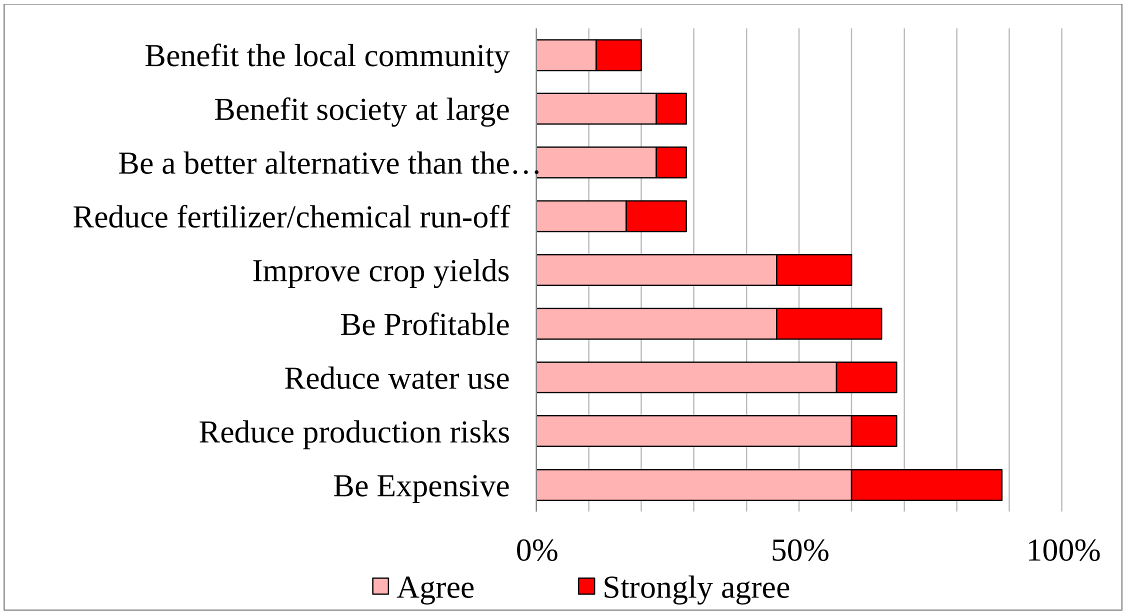


Figure 6.6. Non-adopters' Perception of the BMPs *(N = 35)*

Adopters agreed or strongly agreed that the BMPs are better alternatives than their current systems when compared to non-adopters ($N_{ADOPTERS}$ = 30, 85.7% versus $N_{NON\text{-}ADOPTERS}$ = 10, 28.6%). Adopters also tended to be less neutral than non-adopters regarding this characteristic of the BMPs ($N_{ADOPTERS}$ = 4, 11.4% versus $N_{NON\text{-}ADOPTERS}$ = 15, 42.9%), whereas non-adopters tend to disagree that the BMPs have relative advantage ($N_{ADOPTERS}$ = 10, 28.6% versus $N_{NON\text{-}ADOPTERS}$ = 1, 5.5%). To test if there is a difference between adopters and non-adopters' views relate to whether the BMP is a better alternative, a chi-square test of homogeneity was performed as the sample size was adequate. There was a statistically significant difference in the multinomial probability distributions between the adopters and non-adopters (χ^2 (2) = 23.73, p = 0.01). A post hoc analysis consisting of pairwise comparisons using multiple z-tests of two proportions with a Bonferroni correction was run. There were statistically significant differences in the proportion of adopters who perceived the BMP as a better alternative when compared to non-adopters ($p < 0.01$). The tests used are described in Appendix H, and the results of the tests are shown in in detail in Appendix J.

Statistically significant differences between the two groups existed with respect to other dimensions of BMP perception. Adopters and non-adopters diverged in terms of the way they perceived the cost of the BMPs. More non-adopters perceived the BMPs as expensive (88.6%), relative to adopters (62.9%), whereas more adopters thought that the BMPs would reduce fertilizer or chemical run-off if adopted. The results of the tests can be found in Appendix J.

6.3.4 Perception of BMP as a Better Alternative

Several Chi-Square tests of independence were performed in order to evaluate the relationship between the variable BETTER and other categorical variables: farmers' goals, farm type and crop share. BETTER is an ordered categorical variable, containing three levels. Respondent's answer that indicated agreement or strong agreement with the statement that the proposed BMP was a better alternative than their current practice was coded as 1. If the respondent answered that they disagree or strongly disagree with that statement, their answer was coded as -1. All other responses were coded as 0.

Spearman's rank-order correlation was performed to assess the relationship between farmers' perception of the BMPs being a better alternative and several ordinal or continuous variables. The correlation test was used for variables that were not previously tested for association using chi-square tests. It is preferred to those tests, when the variables correlated are ordinal or continuous. All correlation tests are shown in detail in Appendix K.

There was a strong positive correlation between farmers' perceiving the BMP as a better alternative and perceiving the BMP as having the capacity to improve yields (, $r_s = 0.55$, $p < .01$). Perceiving a BMP as a better alternative than their current water management system was also strongly and positively correlated with perceiving the BMPs as benefiting society at large ($r_s = 0.651$, $p < .01$) and the local community ($r_s = 0.59$, $p < .01$).

Furthermore, perceiving the BMPs as having the capacity to reduce water use ($r_s = 0.42$, $p < .01$), was moderately positively correlated with perceiving the BMPs as a better alternative. Perceiving the BMP as profitable or capable of reducing fertilizer use or chemical run-off was also moderately positively correlated with viewing the BMP as a better alternative. Perceiving a BMP as expensive ($r_s = - 0.39$, $p < .01$), correlated negatively with perceiving it a better alternative.

There were three statements that were moderately but positively correlated with the perception of a BMP as a better alternative. Agreement with the statement that reducing water usage in agriculture was important, was positively correlated ($r_s = 0.35$, $p < .01$) with perceiving the practice as having a relative advantage. This was similar for respondents who considered importance of GHG emission reduction in agriculture ($r_s = 0.35$, $p < .01$) and for the ones who indicated that making best use of scarce resources was important to them ($r_s = 0.28$, $p < .05$).

6.4 BARRIERS TO BMP ADOPTION

Farmers were asked about the degree to which they considered certain items as barriers in their decision to adopt a given BMP. Adopters and non-adopters alike, predominately perceived the following items as potential barriers in their decision to adopt proposed BMPs: the initial cost of the system (67% of respondents, N = 70), stability of the market (67%), low fruit or vegetable prices (64%), and low profit margins (63%). Furthermore, over half of respondents perceived risk of investment and availability of investment capital as important barriers to adoption. The majority of farmers indicated they neither found important nor unimportant having a steep learning curve, thereby selecting the neutral answer choice. Figure 6.7 summarizes these results.

In the subsections below, adopters' perceptions of BMP characteristics are first described, followed by non-adopters' views. The last subsection assesses the difference between adopters and non-adopters concerning perceptions of BMP characteristics.

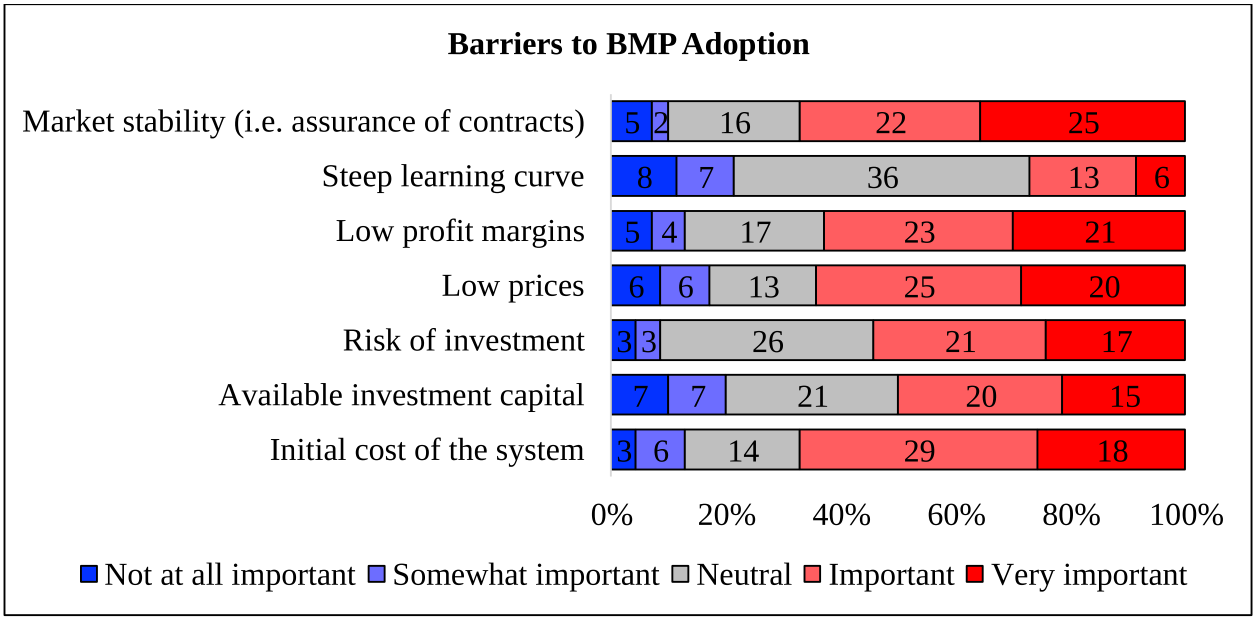


Figure 6.7. Respondents' Perceptions of Barriers to Adoption (N = 70)

6.4.1 Barriers to BMP Adoption Perceived by Adopters

Farmers willing to adopt an improved water management system identified several potential barriers to its adoption. The majority of respondents thought that the following issues could act as barriers to adoption: low profit margins, low crop prices, the initial cost of the system, and availability of investment capital, market instability and the risk of investment. Respondents answered the question: "To what degree could the following factors represent a barrier in your decision to adopt the BMP?" Results are summarized in Figures 6.8 and 6.9.

6.4.2 Barriers to BMP Adoption Perceived by Non – Adopters

Agricultural producers not interested in adopting the proposed BMP indicated that one of the main barriers in considering adoption is market stability. Approximately 69% of surveyed producers found the market's lack of stability as an important barrier to adoption. Initial cost of the system was also mentioned by 57% of non-adopters as a potential barrier, together with risk of investment (51%). Availability of investment capital and steep learning curve in implementing the BMP were neither important nor unimportant. Figure 6.10 shows the frequencies and percentages of responses.

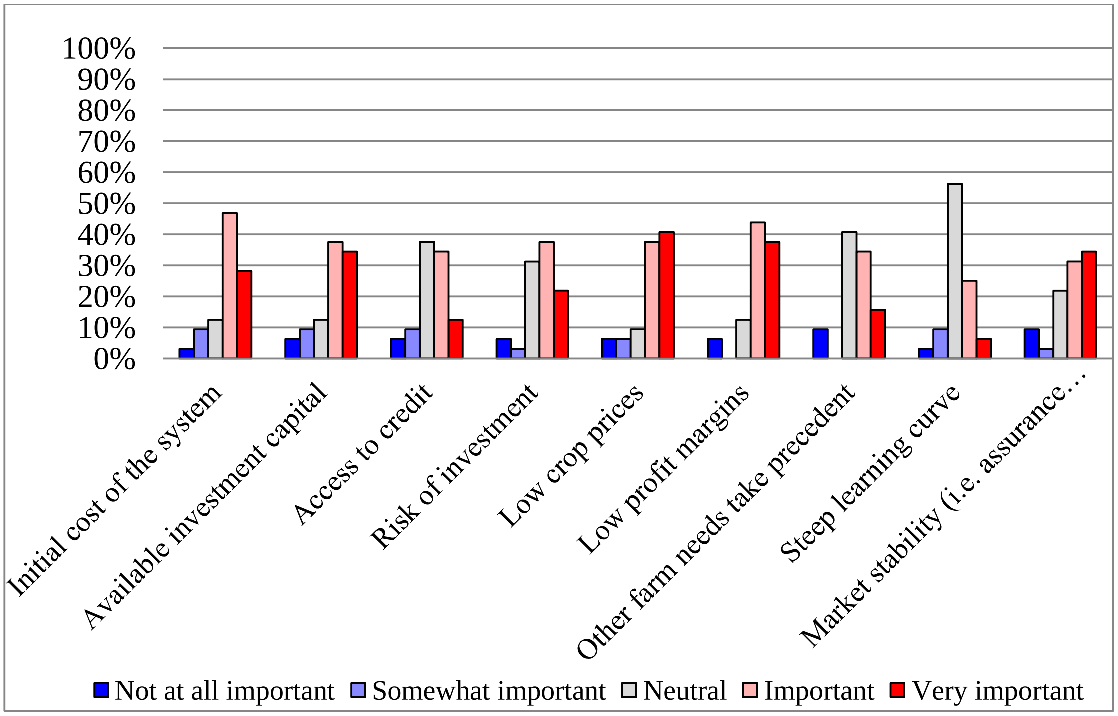


Figure 6.8. Barriers to Growers' Adoption of BMPs *(N = 32)*

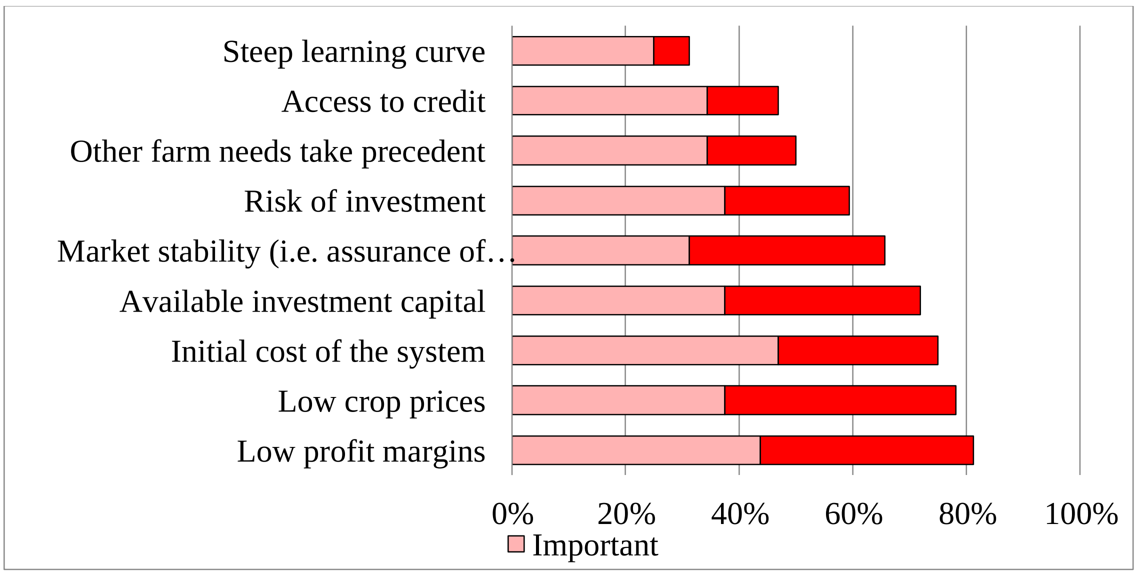


Figure 6.9. Barriers to Growers' Adoption of BMPs *(N = 32)*

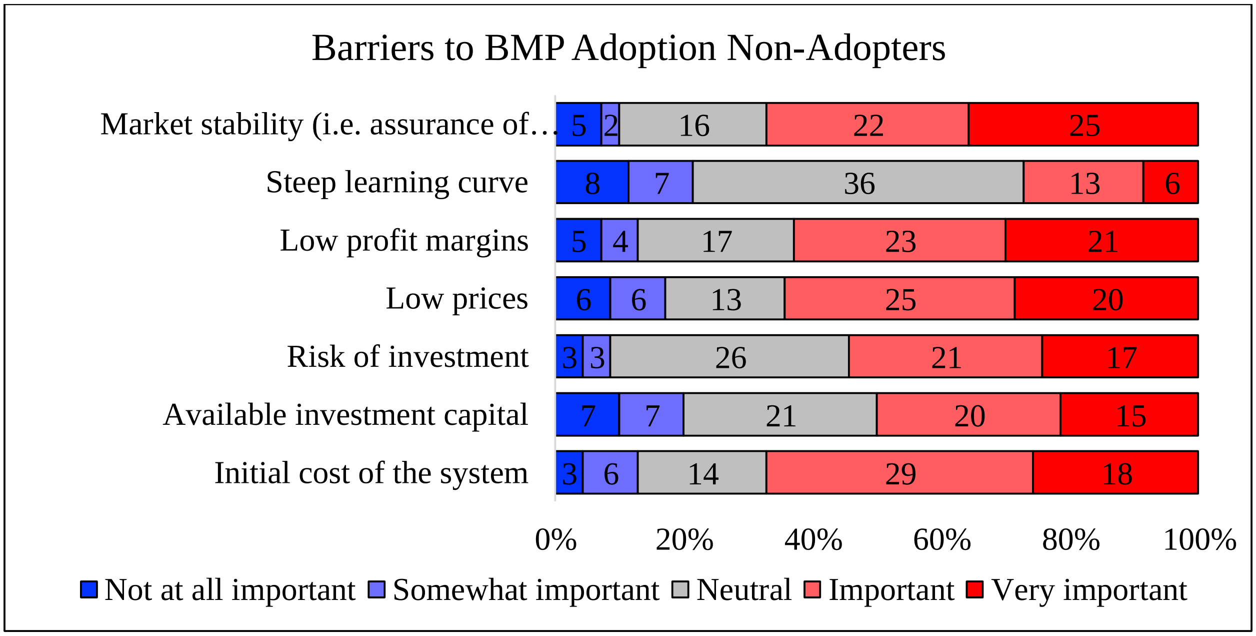


Figure 6.10. Non-Adopters' Perceptions of Barriers to Adoption (N = 35)

6.4.3 Barriers to BMP Adoption – Differences

To determine if a statistically significant difference existed between the binomial proportions of three independent groups[19] with respect to the degree to which farmers consider certain barriers to adoption to be important, on a dichotomous dependent variable – adoption of BMP. The differences between adopters and non-adopters were tested using a Chi-Square Test of Homogeneity. Whenever the sample size requirements for this Test were not met, Fisher's Exact Test was used instead (these tests are further described in Appendix H). There were statistically significant differences between adopters and non-adopters as related to what they consider barriers. Availability of investment capital, low prices and low profit margins were the barriers on which the two groups of producers had different views on.

Adopters reported more frequently than non-adopters that they would find availability of investment capital an important barrier in the adoption of the BMP ($N_{Adopters} = 25$, 71.4% versus $N_{Non\text{-}adopters} = 10$, 28.6%). Adopters also tend to be less neutral than non-adopters about availability

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[19] The groups are: (i) not at all important or somewhat important; (ii) neutral; and (iii) important or very important.

of funds being a limiting factor in adoption $N_{Adopters} = 4$, 11.4% versus $N_{Non\text{-}adopters} = 17$, 48.6%). A Chi-Square test of homogeneity was performed - sample size was adequate (Cochran, 1954). There was a statistically significant difference in the multinomial probability distributions between adopters and non-adopters ($\chi^2 (2) = 14.76$, $p = 0.01$). A post hoc analysis consisting of pairwise comparisons using multiple z-test of two proportions with a Bonferroni correction was conducted. There were statistically significant differences in the proportion of adopters who perceived availability of investment capital as a potential barrier when compared to non-adopters.

Statistically significant differences between the two groups exist and they relate to two other barriers. More adopters considered low prices as an important potential barrier (80%), by comparison with non-adopters (48.6%). Results were similar when looking at low margin as a potential barrier for adoption. The results of the tests are presented in Appendix H.

6.5 PERCEPTIONS OF ENVIRONMENTAL RESPONSIBILITIES

Respondents were asked about their perception regarding farmers' responsibilities towards safeguarding the environment. A large majority of adopters and non-adopters (90% of respondents, N = 70) alike indicated that making best use of scarce resources is important to them. Respondents most commonly (87%) believe that farmers should be responsible for minimizing environmental damages from their farms. However, when asked if farmers should be the ones supporting costs associated with environmental damages because of their farming, respondents' views were divided – 36% of farmers in the sample disagreed with this statement, 34% were neutral and 30% agreed with the statement. Furthermore, approximately 63% of farmers indicated that they agree with the statement that society should share the costs of minimizing agriculture's impact on the environment. In addition, cost-share programs were perceived by approximately 86% of respondent as representing good use of public funds.

Finally, the respondents were asked if reducing GHG emissions and water usage coming from agricultural production were important things to them. Farmers thought to a larger degree (81%) that reducing water use was slightly more important than reducing GHG emissions (70%). Figure 6.11 summarizes these results.

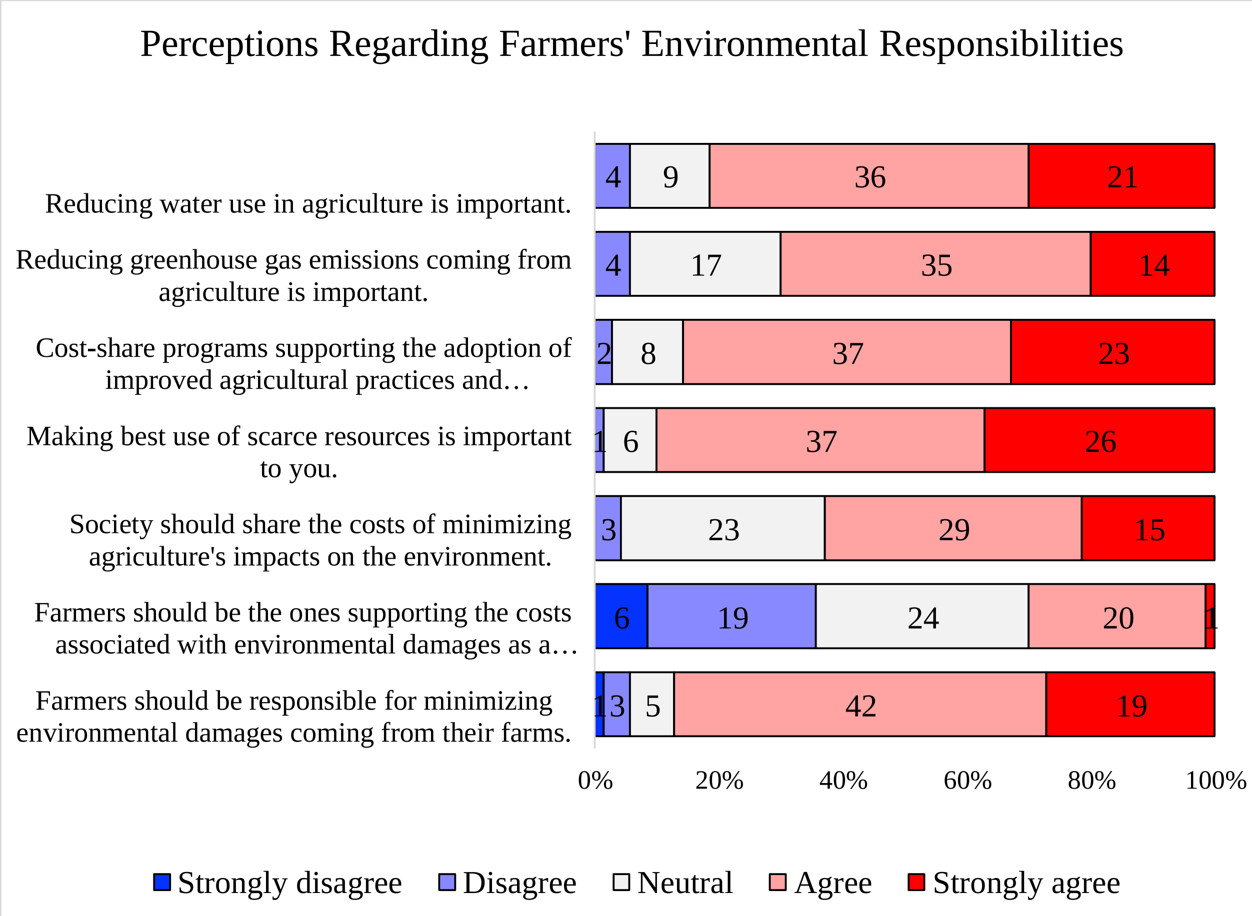
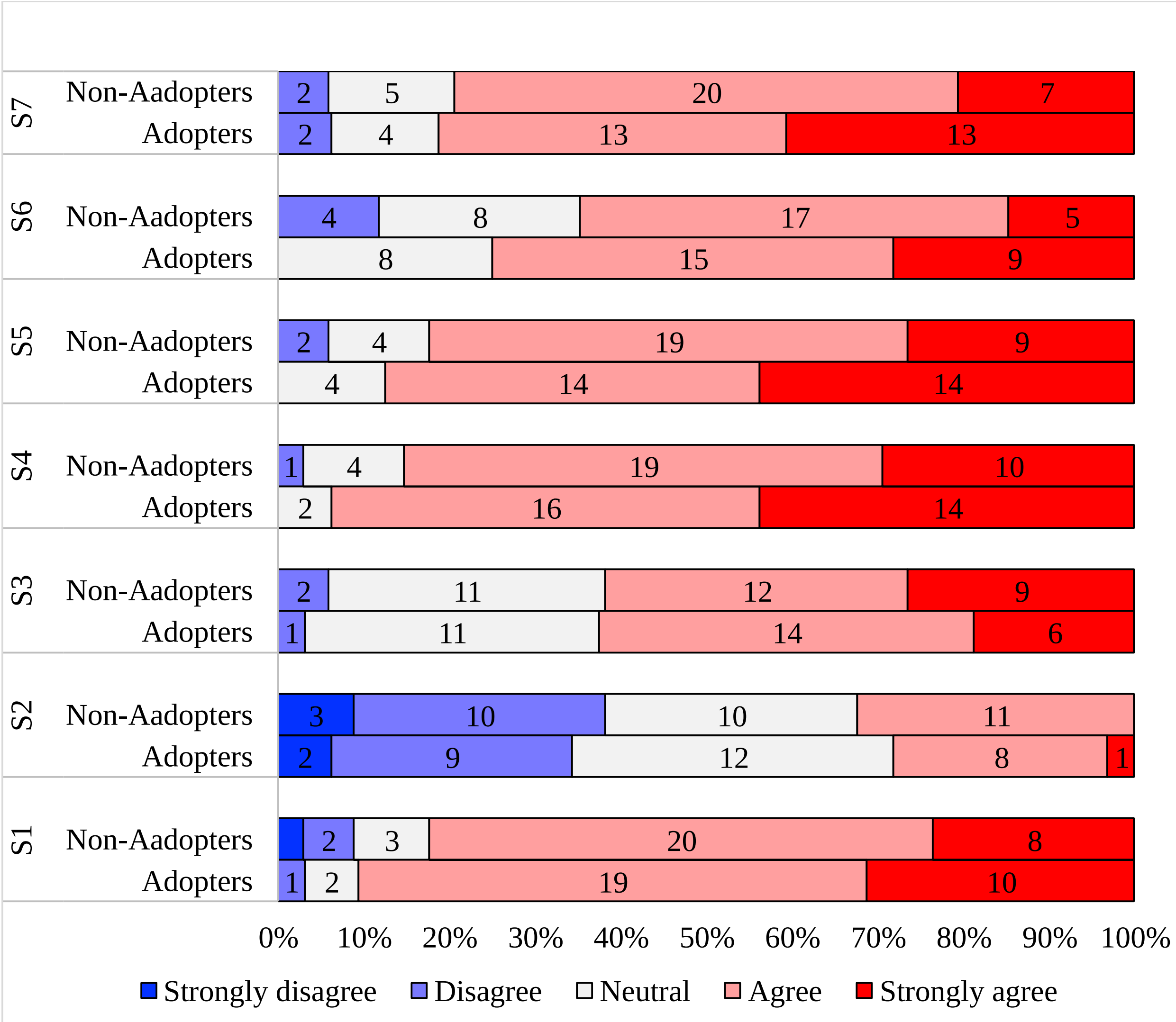


Figure 6.11. Respondents' Perceptions of Environmental Responsabilities *(N = 70)*

In the subsections below, adopters' views are first described, followed by non-adopters' views. Given that no statistically significant differences exist between adopters and non-adopters regarding the way they perceive environmental responsibilities; no section was included to discuss it. However, test results for assessing group differences can be found in Appendix H.

6.5.1 Perception of Environmental Responsibilities by Adopters

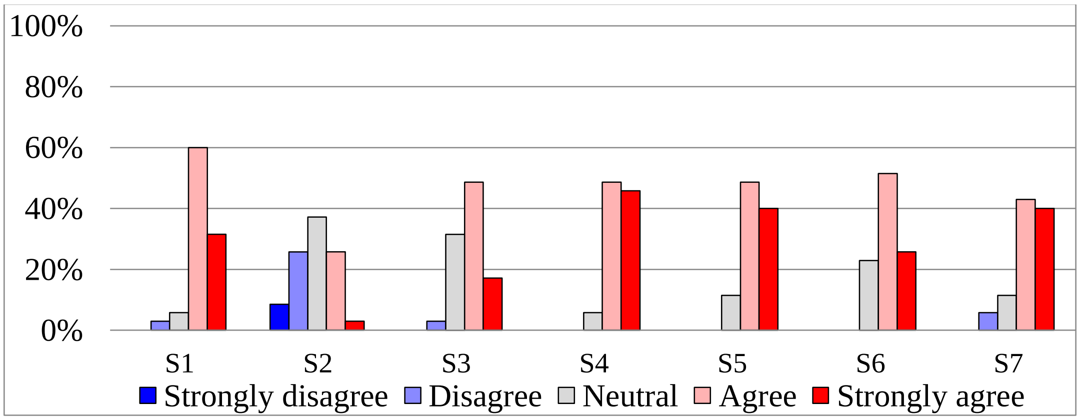
Overall, agricultural producers, who were willing to adopt improved water management systems, had a positive general attitude towards the environment and their responsibilities in safeguarding it. The majority of adopters agreed that making best use of scarce resources was important for them and that farmers should be responsible for minimizing environmental damages coming from their farms.



S1	Farmers should be responsible for minimizing environmental damages coming from their farms.
S2	Farmers should be the ones supporting the costs associated with environmental damages as a result of their farming.
S3	Society should share the costs of minimizing agriculture's impacts on the environment.
S4	Making best use of scarce resources is important to you.
S5	Cost-share programs supporting the adoption of improved agricultural practices and technologies represent good use of public money.
S6	Reducing greenhouse gas emissions coming from agriculture is important.
S7	Reducing water use in agriculture is important.

Figure 6.12. Respondents' Perceptions of Environmental Responsabilities by Adopters and Non-Adopters *(N = 70)*

In addition, they also agreed that reduction of water use and GHG emissions coming from agriculture is important. They further believed that cost-share programs for the support of improved practices and technologies represents a good use of public funds. However, adopters were ambiguous regarding the statement that "farmers should be the ones supporting the costs associated with environmental damages as a result of their farming". Respondents' answers to the question: "State the level to which you agree or disagree with the following statements …" are summarized in Figures 6.13 and 6.14.

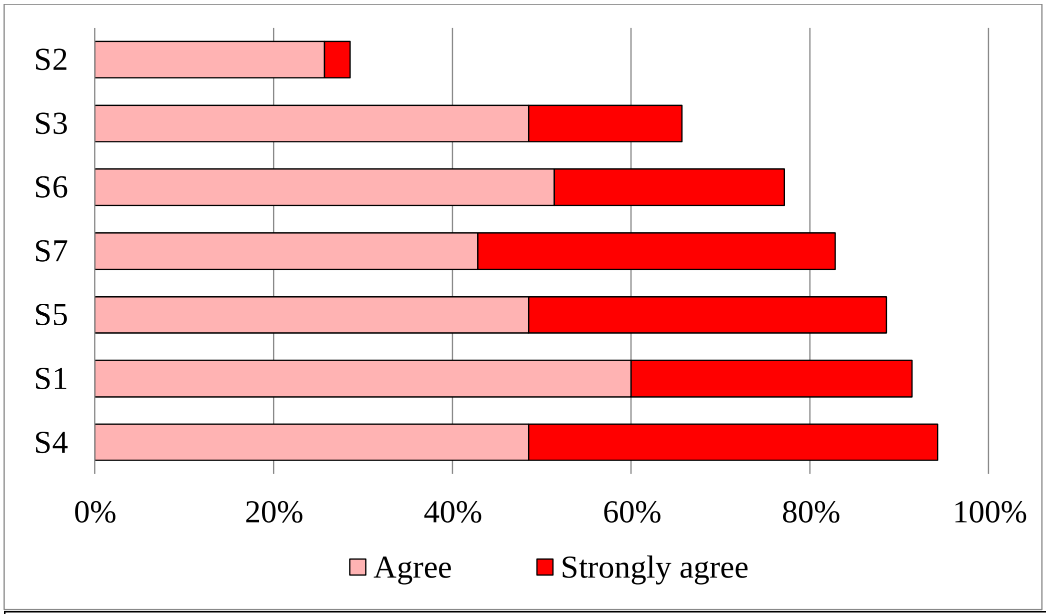


S1	Farmers should be responsible for minimizing environmental damages coming from their farms.
S2	Farmers should be the ones supporting the costs associated with environmental damages as a result of their farming.
S3	Society should share the costs of minimizing agriculture's impacts on the environment.
S4	Making best use of scarce resources is important to you.
S5	Cost-share programs supporting the adoption of improved agricultural practices and technologies represent good use of public money.
S6	Reducing greenhouse gas emissions coming from agriculture is important.
S7	Reducing water use in agriculture is important.

Figure 6.13. Adopters' Attitudes Towards the Environment and Society *(N = 35)*

6.5.2 Perception of Environmental Responsibilities by Non-Adopters

Overall, agricultural producers not willing to adopt improved water management systems had a positive general attitude towards the environment and their responsibilities in safeguarding it, which were similar to the adopter group. Respondents' answers to the question: "State the level to which you agree or disagree with the following statements …" are summarized in Figures 6.15 and 6.16.



S1	Farmers should be responsible for minimizing environmental damages coming from their farms.
S2	Farmers should be the ones supporting the costs associated with environmental damages as a result of their farming.
S3	Society should share the costs of minimizing agriculture's impacts on the environment.
S4	Making best use of scarce resources is important to you.
S5	Cost-share programs supporting the adoption of improved agricultural practices and technologies represent good use of public money.
S6	Reducing greenhouse gas emissions coming from agriculture is important.
S7	Reducing water use in agriculture is important.

Figure 6.14. Adopters' Attitudes Towards the Environment and Society *(N = 35)*

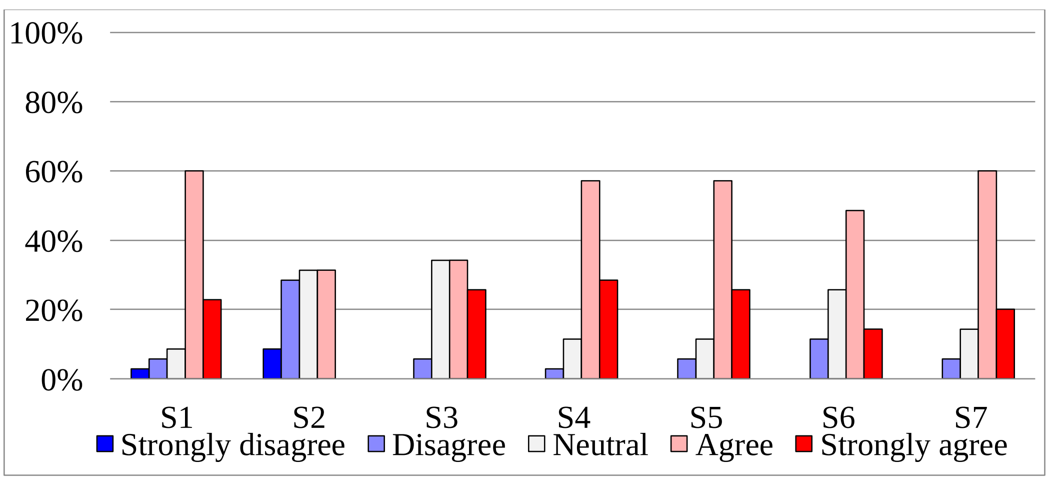


Figure 6.15. Non-Adopters' Attitudes Towards the Environment and Society *(N = 35)*

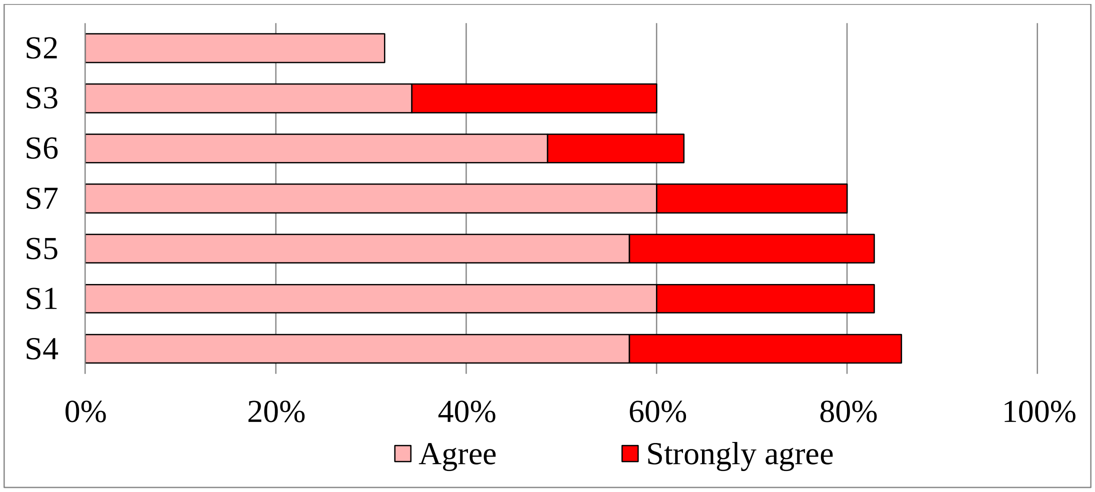


Figure 6.16. Non-Adopters' Attitudes Towards the Environment and Society *(N = 35)*

6.6 FACTORS AFFECTING ADOPTION DECISIONS

Adopters were asked to express the extent to which they consider certain factors important in their decision to adopt an improved water management system. Respondents' answers to the question: "How important are the following factors in your decision to adopt the BMP?" are summarized in Figure 6.17. It is important to note that majority of answer choices for this question were presented to all adopters, some variations existed, hence the difference in the number of respondents, present in the chart below in parenthesis. Before answering this question, participants were shown information containing characteristics of the BMP, which likely had an effect on their subsequent choices respondents made.

One of the most important factors identified by adopters was the BMPs' capacity to increase crop yields. All adopters found this characteristic to be either important of very important when deciding to adopt or not. Profitability of investment was identified as an important factor by 94% (N=35) of respondents. Furthermore, being able to trial the technology was indicated by majority of respondents (77%, N=35) as an important factor in deciding whether they adopt or not a BMP. It is important to note that these factors sought to be important are directly linked to financial benefits of adoption. Other important factors identified by producers, which can also be categorized as financial benefits, were a BMP's capacity to reduce water use, reduced labour cost (63%, N=32), increased crop quality (92%, N=13), etc.

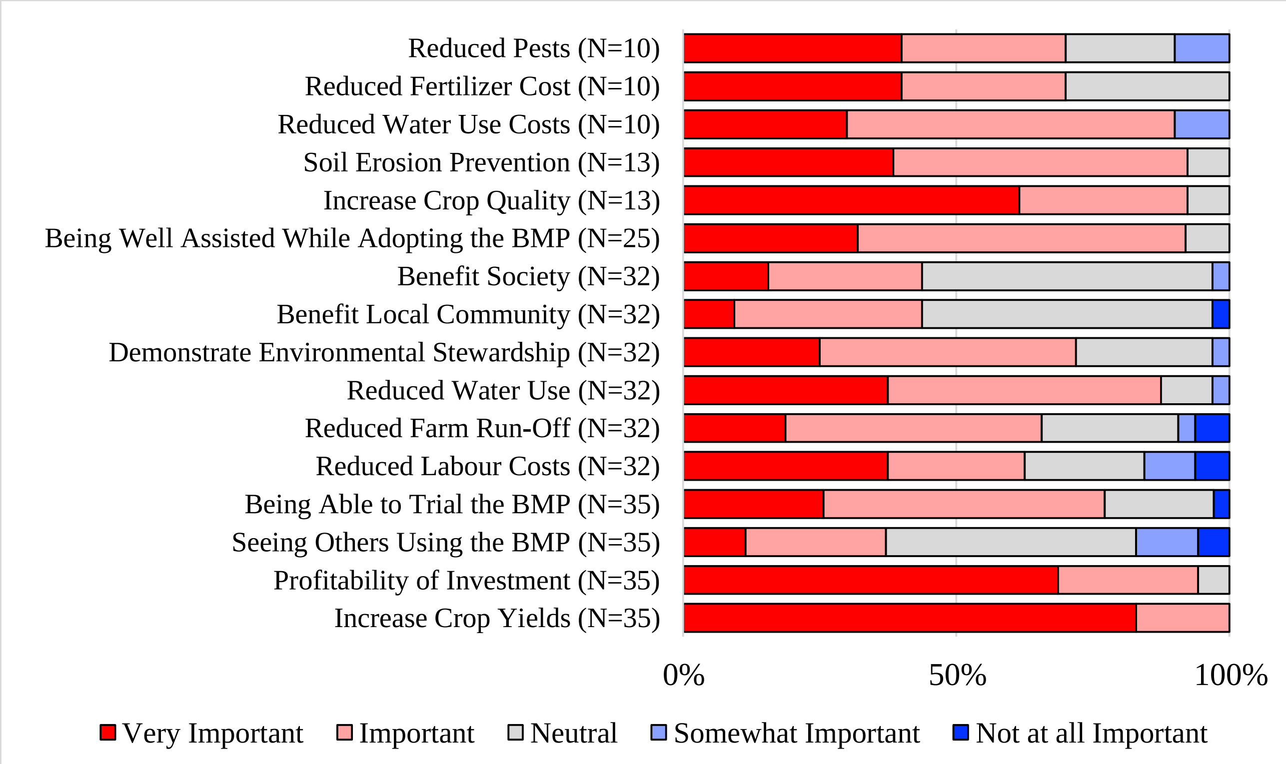


Figure 6.17. Factors Influencing BMP Adoption as Indicated by Adopters

Amongst important factors, one can also see some that are not necessarily linked to financial benefits. An important element in producers' adoption of a BMP is related to their aspiration to demonstrate environmental stewardship. This factor was nominated by 72% (N=32) of respondents as an important factor influencing their adoption decision. Furthermore, farm run-off was also important for 66% (N=32) of producers. Availability of assistance during adoption is another important factor identified by majority of respondents (92%, N=25).

Producers saw three factors as not having either a positive or a negative impact on their decision to adopt. These were capacity of the BMP to benefit society, benefit the local community, and seeing their peers using the BMP. This outcome appears to reinforce the statement made previously that farmers are motivated to adopt if the new practice or technology provides direct financial benefits to them. More so, they remain indifferent to the potential benefits the adoption might bring to society, when deciding whether to adopt a BMP or not.

Non-adopters were also asked about the factors contributing to their decision. Respondents answers to the question: How important are the following factors in your decision to not adopt the BMP?” are summarized in Figure 6.18.

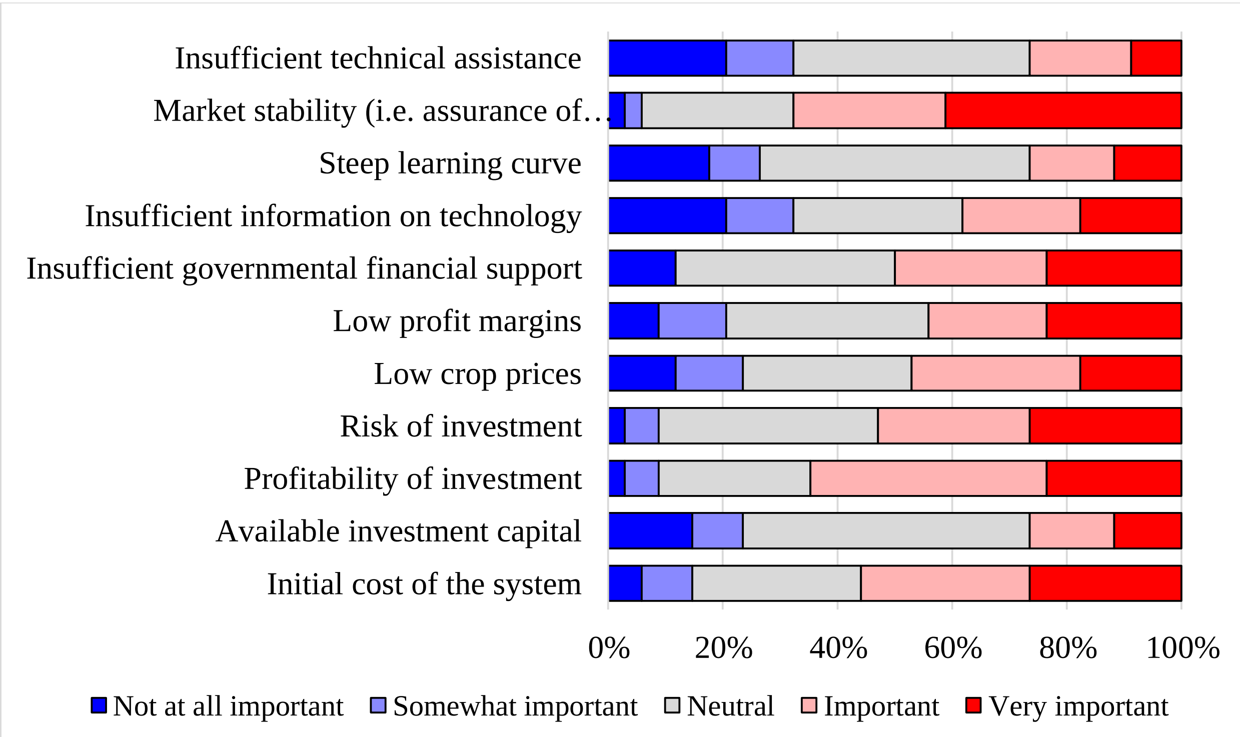


Figure 6.18. Factors Contributing to BMP Related Decision by Non-Adopters (N = 34)

Most producers indicated that market instability (68%), profitability of investment (65%), initial cost of the system (56%), and the risk of investment (53%) were important factors that would deter them from adopting the BMPs. Another factor mentioned by half of the respondents (50%) was the fact that they consider insufficient governmental financial support for these systems as an important reason in their decision to not adopt the proposed BMPs.

Non-adopters marked several factors as least important in their decision-making process. About 32% of respondents indicated that not having sufficient technical assistance or information related to the BMP are not important factors in their adoption decisions. Furthermore, a steep learning curve does not represent an important factor in their decision, and surprisingly neither does the availability of investment capital.

These findings show that both adopters and non-adopters are influenced by economic factors when deciding to adopt or not a BMP. While non-economic factors also contribute to their decision-making, the economic group of factors is predominant amongst surveyed producers. Decision by adopters is motivated by the BMPs' capacity to increase yields, its profitability, trialability and availability of assistance in the adoption process. Non-adopters identify market instability, profitability of investment, initial cost of the BMPs, risk of investment and insufficient governmental support, as important factors to support their decision to not adopt the proposed BMPs.

6.7 PRODUCERS' VIEWS ON MEASURES TO INCREASE ADOPTION

Non-adopters were asked to answer the following question: "How important would you find the following policy changes in influencing your decision regarding the adoption of a {specific BMP depending on the group of producers' they were part of}?" They were provided with four choices, which they ranked in accordance with their level of agreement for each one of the proposed policy responses.

First type of measure was "increase in the share supported by the government for the {proposed BMP}. Please indicate the necessary governmental cost share if you consider this factor relevant (i.e., 10%)". Approximately 59% (N=34) of producers consider an increase in the cost share supported by the government, a policy response likely to influence their adoption decision (Figure 6.19). The increase in the amount supported ranged from 0% to 70%, with an average value of 34%. However, 55% of producers (N=29), mentioned that an increase in governmental support by 30% - 50% would be sufficient to influence their adoption decision.

The second measure focused on governmental assistance in the form of either additional technical support, or by providing more information regarding the characteristics of the proposed BMPs. Majority of respondents (56%) considered that an increase in technical assistance and/or additional information about the proposed BMPs, would change their opinion regarding adoption.

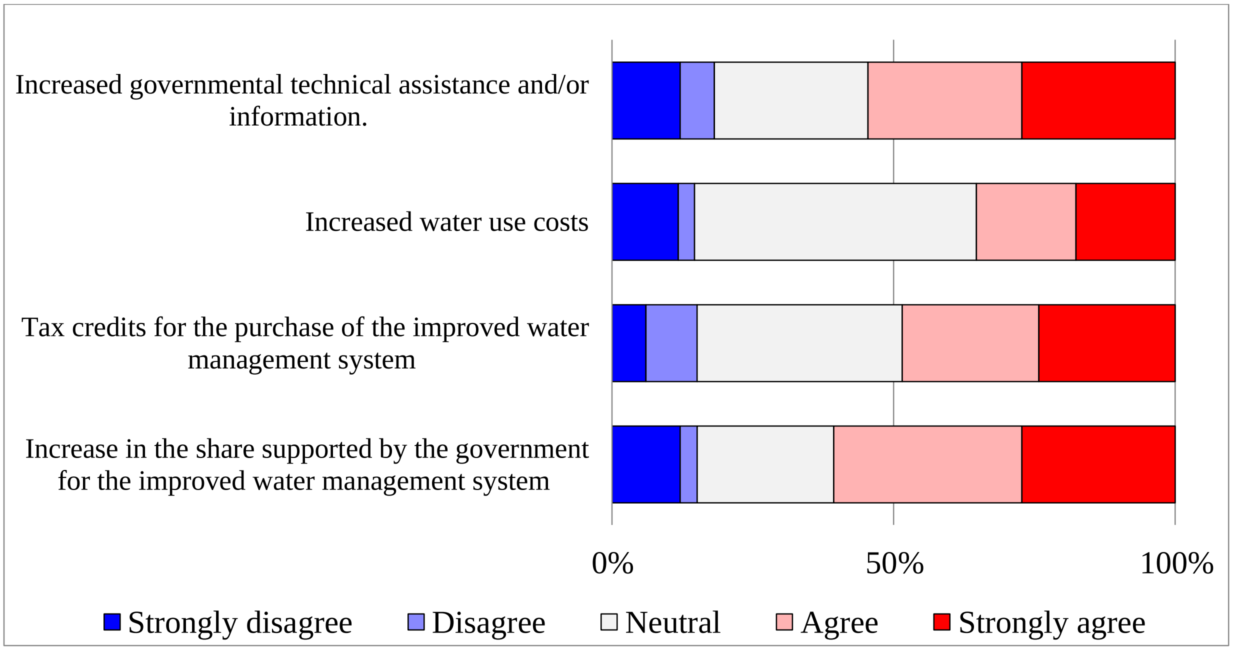


Figure 6.19. Non-Adopters' Opinion Regarding Importance of Policy Changes in Influencing Adoption *(N = 34)*

For the third measure, producers were asked about tax credits for the purchase of the new inputs needed for adopting the new BMP. The largest group which consisted of 47% of respondents (N=34), agreed with this policy response, while 35% were neutral to it, and 18% disagreed with this policy solution. The proposed tax percentage reduction ranged from 0% to 100%; however, the average was of 40%.

Finally, producers were asked about the extent to which a policy response that included an increase in water use costs would influence their adoption decision. This policy option was less popular, with only 35% of respondents supporting it, 50% were neutral to it, and 15% disagreed that this governmental response would influence their adoption decision. Producers, who were in agreement with this policy, suggested an average increase of 18% in water use costs.

In summary, producers not willing to adopt the proposed BMPs thought that an increase in the share of total cost of the investment supported by the government, together with increased governmental technical assistance and tax credits could be pivotal factors in changing their decision in favour of adoption of the said BMP.

6.8 DETERMINANTS OF ADOPTION AND PERCEPTION

6.8.1 Determinants of BMP Adoption

Factors influencing farmers' decisions regarding adoption of agricultural practices or technologies is an area that has been vastly researched. However, previous research has highlighted the importance of these factors in context specific conditions and focusing on specific innovations or practices and technologies. This section provides details of analysis for this study that focuses on identifying the determinants of farmer's adoption of improved water management BMPs, using data from a survey of 70 fruit and vegetable growers in Ontario and Québec.

Analysis was undertaken using the logit regression models. These were developed to identify the factors influencing farmer's BMPs adoption. Findings suggest that a multitude of factors influence decisions, some related to farmers' characteristics – farming goals, farming experience and perceptions of BMPs, while other factors are related to the characteristics of the farm - farm size and proportion of sales coming from the commodity where the BMP is used.

6.8.1.1 Models Specification

The models were developed based on the results of the study survey. In this survey, after a description of the BMP, respondents were asked to answer the following question:

- For cranberry producers -- "Would you adopt subirrigation for your cranberry production?"
- For tomato producers -- "Would you adopt subsurface drip irrigation for your tomato production?"
- For onion producers -- "Would you adopt sprinkler irrigation for your onion production?"

Responses were coded as 1=Yes and 0=No, and were named under the ordered categorical variable named ADOPT. Three models were developed. The first one included only those variables that reflect farmers' perceptions of the BMPs and characteristics of the farmers. The second model included factors that encompass farm and farmer characteristics. The third model combines all the variables found in the previous two models. The models' specifications are shown below and Table 6.3 provides details for variables present in the models.

Model 1 (M1)

$$ADOPT = \beta_0 + \beta_1 EXPERIENCE + \beta_2 BETTER_{NEUTRAL} + \beta_2 BETTER_{DISAGREE} + \beta_3 GOALS + \varepsilon_i \quad (6.1)$$

Model 2 (M2)

$$ADOPT = \beta_0 + \beta_1 CROP\ SIZE + \beta_2 CROP\ SALES\ SHARE + \beta_3 EDUCATION_{MID} + \beta_4 EDUCATION_{LOW} + \varepsilon_i \quad (6.2)$$

Model 3 (M3)

$$ADOPT = \beta_0 + \beta_1 CROP\ SIZE + \beta_2 CROP\ SALES\ SHARE + \beta_3 EDUCATION_{MID} + \beta_4 EDUCATION_{LOW} + \beta_5 BETTER_{NEUTRAL} + \beta_6 BETTER_{DISAGREE} + \beta_7 GOAL + \varepsilon_i \quad (6.3)$$

Table 6.3. Description of Variables Included in the Binary Logistic Models

Acronym	**Description**
ADOPT	Distinguishes between adopters and non-adopters
EXPERIENCE	Years of farming experience
BETTER	Perception of BMP as a better alternative than current practice
GOALS	Farming related goals
CROP SIZE	The acres allocated to the crop related to the BMP adoption
CROP SALE SHARE	Percentage of sales corresponding to the crop of interest
EDUCATION	Farmer's level of education

To determine if a linear relationship exists between ADOPT and all the independent variables, a logistic regression was estimated with ADOPT as the outcome and each of the variables listed on the right-hand side of equations 6.1 to 6.3 as independent variables. Subsequently, the model, which only consists of the intercept (i.e., β_0) to the fit of the model, was compared with the intercept and the independent variable (i.e., the model with parameters β_0 and $\beta_{EXPERIENCE}$). This comparison was conducted using the Likelihood Ratio Test in which the test statistic (TS) is shown in equation 6.4:

$$TS = -2 \log L_{Reduced} - (-2 \log L_{Full}) \quad (6.4)$$

The TS has a Chi-Square distribution with the degrees of freedom equal to the difference in the number of parameters between the two models. With p-values < 0.05, sufficient evidence was found to conclude that the model, which includes any of the following variables: EXPERIENCE, BETTER, GOALS, CROP SIZE, CROP SALES SHARE and EDUCATION, is a better model than the model containing only the intercept. This led to the conclusion that there is a relationship between the above-mentioned independent variables and the ADOPT variable.

For each model, a Pseudo model fit statistic was calculated using the following formula:

$$1- (-2 \log L_{Full} / -2 \log L_{Reduced}) \tag{6.5}$$

This statistic was estimated for each one of the models containing only one of the independent variables. Based on these simple models, the following results were obtained. When modelling ADOPT only using EXPERIENCE as an independent variable, results show that 11.58% of adoption is explained by farmers' experience. The next factor used to model adoption was the categorical variable BETTER. This independent variable represents the degree to which growers agree that the proposed BMP is a better alternative than the current water management systems used. This simple model shows that 26.58% of adoption can be explained by the degree to which farmers perceive the BMP as a better alternative. Farmers' GOALS explained 10.23% of the outcome variable, and the farm area allocated to the production of tomatoes, cranberries or onions (CROP SIZE) variable accounted for 5.2% of variability. In addition, the percentage of sales accruing from these fruits and vegetables, out of total farm sales explained 9.4% of adoption decisions. Lastly, EDUCATION was used to explain adoption, and the results indicated that this independent variable explains 12.16% of adoption.

To determine if there was a complete separation (i.e., groups of the dependent variable values were perfectly separated by an independent variable), five scatter plots of EXPERIENCE, BETTER, GOALS, CROP SIZE, CROP SALES SHARE, EDUCATION versus ADOPT were created. These were assessed visually using scatter plots indicated that the ADOPT variable was not separable with respect to either one of the variables. This absence of separation is required for accurately estimating coefficients.

The robustness of regression models can also be perturbed by influential cases, such as the outliers or those that can influence the results of the regression model significantly. Several indicators are generally used to identify these effects. Amongst the common indicators are standardized Pearson's residuals, deviance, Pregibon's leverage or Pregibon's Delta-Beta similar and Cook's distance (King, 2008). Pearson's Residuals represent the difference between observed and predicted values. Hence, a case with a large residual value can be an outlier, for which the model fits poorly. It is indicated that instead of simply discarding of these cases, they are revised to make sure there are no coding issues. Outliers can be symptomatic of other issues as well; they could be an indication that key variables are missing from the model.

Standardized residual plots are good means of exploring the dispersion of the difference between observed and predicted values using the created model. Pearson's standardized residuals should lie between -2.58 and +2.58 and according to Bilder and Loughin (2014, p.289), only 5% of values should be beyond this range and none beyond ±3. To determine if there were any outliers, these standardized residuals a plot was created. Values outside the ±2.58 interval were considered outliers, at 1% level of significance. As it can be visually assessed using Figure L.1 in Appendix L, several outliers were found for each one of the models. The outliers were excluded from the dataset, and the regression analysis was re-estimated.

Influential cases were identified by calculating Cook's distance coefficients and for finding observations that had a high leverage, Pregibon's leverage coefficient was calculated. On this criterion, for the first model, cases with identification numbers 120 and 115 were discarded, with the first observation being considered influential (Cook's distance > 4/n), where n is sample size (UCLA, 2019) and the second one was considered to have high leverage (Pregibon's leverage > 2(k +1)/n, where k is the number of predictors and n is the sample size (Belsley et al., 1980). For the second model, cases 101, 107 and 306 were discarded for being considered influential, and no cases were found to have high leverage. All results are show in in Figures L.2 and L.3, in Appendix L.

To test the independence of the errors, Durbin Watson Test Statistic (TS) was used. For M1, estimated TS was 1.96. From the Durbin Watson significance table values, d_U and d_L were obtained for n=69 (one outlier was removed) and seven parameters excluding the intercept. These values were d_U = 1.68 and d_L = 1.25. For M1, the Durbin-Watson statistic was greater than d_U, resulting in a non-rejection of the null hypothesis. This led to the conclusion that the error terms have no autocorrelation. Similar results were obtained for M2 and M3.

In terms of sample size requirements, while there are no definite rules related to the number of observations required when estimating logit regression model parameters, the existing literature provides some guidance. Previous studies recommend that for each estimated parameter there should be a minimum of 10 cases in the dataset (Pedduzi et al., 1996), while others mention a minimum of 20 cases (Harrell et al., 1996). However, a more recent study which revisited these recommendations, shows that a relaxation of the rule of thumb of 10 cases can be made, as they observed that *"only a minor degree of extra caution is warranted, in particular for plausible and highly significant associations hypothesized a priori"* for models that were estimated using only 5-9 variables per case (Vittinghoff & McCulloch, 2007). For the first two models, the sample size was 70, while for the third model only 66 cases were introduced in the model.

Multicollinearity is problem in a regression model, not because it affects the model's predictive capacity, but because it might produce unreliable coefficients and inflated standard errors (King, 2008). This problem occurs in a regression model if one or more predictors are correlated with each other. Tolerance and variance inflation factor (VIF) are two indicators that are commonly used to examine the strength of association between independent variables within a regression model. Results indicate that neither one of the three developed models had multicollinearity issues. Tolerance scores of 0.1 or lower are indicative of multicollinearity issues. For M1, high tolerance scores ranging from 0.78 to 0.92 were obtained. For the M2 and M3, tolerance scores varied between 0.64 and 0.90, and 0.61 to 0.88, respectively. Similarly, the VIF scores were also below the threshold of concern with values ranging between 1.07 and 1.64.

6.8.1.2 Models Evaluation

Based on the model fitting information, M3 is the one performing better on multiple indicators, when compared to M1 and M2. For each of the models, the fit of the null model (one with only containing the intercept) was compared with the fit of the full model. This comparison was realized using the LR (likelihood ratio) Test[20]. With P-values < 0.01, for each one of the models, there was evidence to conclude that the full models are better models than the null ones. The likelihood ratio (LR) under Chi-Square quantifies the variability attributable to the model, and

[20] In SPSS the LR Test results are provided in the "Omnibus Tests of Model Coefficients"

implicitly evaluates the extent to which a set of predictors improve the model. The highest LR indicator 65.71 was obtained for M3, in comparison to those for M1 and M2 of 47.65 and 45.46, respectively, indicating that M3 explains better the outcome variable.

The log likelihood (LL) for the full models, or more specifically the -2LL[21] is another indicator of model fit, with lower values representative of better fit. The -2LL value for Model 3 was 25.72, as against 43.78 for Model 1 and 41.78 for Model 2 (Table 6.4).

Table 6.4. Measures of Fit for Logit Models

Measure	*Model 1*	*Model 2*	*Model 3*
LR	47.65	45.46	65.71
-2 log L_{Model}	43.78	41.78	25.72
-2 log L_{Full}	91.43	87.24	91.43
Pseudo Model Fit R^2	0.52	0.52	0.72
Cox and Snell R^2	0.51	0.51	0.63
Nagelkerke / Cragg & Uhler's R^2	0.69	0.69	0.84
AUC	0.94	0.92	0.97
AIC	53.78	51.78	81.71
BIC	64.73	63.03	99.23
% Correctly Predicted	83.3%	88.9%	87.9%
Specificity	78.1%	91.2%	88.2%
Sensitivity	88.2%	86.2%	87.5%

In addition to the above three criteria for evaluation, several other measures were also estimated and compared among the three models. One of these measures was pseudo R^2 value, as they are indicative of the percentage of variation in the outcome variable that is explained by the model. Cox and Snell and Nagelkerke / Cragg & Uhler's pseudo R^2 values were calculated and used to assess the models. In addition to these two values, a pseudo model fit statistic was also calculated, using the following formula 1- (-2 log L_{Full} / -2 log $L_{Reduced}$), where $L_{reduced}$ is the model containing only the intercept and L_{Full} the model with intercept and predictors. Based on these values, the first two models explained somewhere between 51% and 69% of variability in ADOPT, whereas the third model explained somewhere between 63% and 84% (Table 6.5). These results

[21] The multiplication with 2 is used to transform the log-likelihood into a Chi-Square distribution, important for testing statistical significance

suggest that the third model is the best model among the three estimated models based on explanatory power.

Table 6.5. Parameter Log Odds Estimates for the Logistic Regression Model for Factors Influencing Fruit and Vegetable Growers' Adoption of BMP Decision in Ontario and Québec

Model 1	***Coefficient (log odds)***	***S.E.***	***Wald***	***df***	***Sig. (p)***	***Odds Ratio***	***95% CI (lower)***	***95% CI (upper)***
EXPERIENCE	-0.08	0.03	6.08	1	0.01	0.93	0.87	0.98
BETTER			6.67	2	0.40			
BETTER(Neutral)	-22.06	12791	0.00	1	0.99	0.00	0.00	0.00
BETTER (Disagree)	-2.12	0.82	6.67	1	0.01	0.12	0.02	0.60
GOALS	2.20	0.82	7.13	1	0.01	8.99	1.79	45.06
CONSTANT	2.05	0.88	5.46	1	0.02	7.80		
Model 2	***Coefficient (log odds)***	***S.E.***	***Wald***	***df***	***Sig. (p)***	***Odds Ratio***	***95% CI (lower)***	***95% CI (upper)***
CROP SIZE	0.03	0.01	12.63	1	0.00	1.03	1.01	1.05
CROP SALES SHARE	0.06	0.02	9.25	1	0.00	1.06	1.02	1.11
EDUCATION			7.51	2	0.02			
EDUCATION (MID)	-5.30	2.03	6.83	1	0.01	0.01	0.00	0.27
EDUCATION (LOW)	-2.06	1.04	3.94	1	0.05	0.13	0.02	0.97
CONSTANT	-6.28	2.08	9.11	1	0.00	0.00		
Model 3	***Coefficient (log odds)***	***S.E.***	***Wald***	***df***	***Sig. (p)***	***Odds Ratio***	***95% CI (lower)***	***95% CI (upper)***
CROP SIZE	0.04	0.02	6.96	1	0.01	1.04	1.01	1.08
CROP SALE SHARE	0.03	0.03	1.31	1	0.25	1.03	0.98	1.08
EDUCATION			7.47	2	0.02			
EDUCATION (MID)	-11.79	4.32	7.46	1	0.01	0.00	0.00	0.04
EDUCATION (LOW)	-5.55	2.49	4.98	1	0.03	0.00	0.00	0.51
BETTER			6.67	2	0.04			
BETTER(Neutral)	-8.64	3.37	6.95	1	0.01	0.00	0.00	0.13
BETTER (Disagree)	-5.76	2.50	5.32	1	0.02	0.00	0.00	0.42
GOALS	1.69	1.31	1.68	1	0.20	5.44	0.42	70.45
CONSTANT	-0.86	2.53	0.12	1	0.73	0.42		

Log Odds *– also referred to as logit is the natural log of the odds ratio of an outcome;*
S.E *– coefficients standard errors, used for testing whether the parameter is significantly different from 0; by dividing the parameter estimate by the standard error the t-value is obtained;*
Wald *– Test used to determine whether the parameter is different than 0, test with a chi-square distribution;*
Df *– degrees of freedom for each one of the parameters;*
Sig. (p) *– p-value of the 2 tailed test*
Odds Ratio *– exponentiation of the log odds*
95% CI lower *–lower bound for the 95% confidence interval expressed as odds ratio*
95% CI upper *– upper bound for the 95% confidence interval expressed as odds ratio*

Another insight into the robustness of models is given by classification-based approaches, like Area Under the Curve (AUC) and percentage of correctly classified cases. In terms of performance related to predicting the proper outcome, M3 scored better than M1 and M2. For the first model, the AUC was 0.94, and it correctly classified 83.3% of the cases. For M2 the AUC value was 0.92 and the model correctly classified 88.9% of cases. The highest values of AUC were obtained for M3, for which the AUC was 0.97 and the model correctly classified of 87.9% of cases.

In order to get further information on the quality of the model, Akaike's Information Criterion (AIC) together with the Bayesian Information Criterion (BIC) were calculated. Both measures provide information about the parsimony[22] of the developed models. These criteria penalize models for including more variables as well as allow for comparison of non-nested models[23]. A model with a lower information criteria score is preferred to one with a larger score. From the three developed models, M2 outperformed the other ones, as shown in Table 6.3.

6.8.1.3 Result of Estimated Models

The estimated coefficients for each one of the three models are summarized in Table 6.5, which contains parameter log odds estimates for the three logistic regression models containing factors influencing fruit and vegetable growers' adoption decision.

For the first model (M2), estimated coefficients suggest that growers with more farming experience were less likely to adopt the proposed BMPs. In contrast, farmers, whose goals were predominantly financial, were more likely to adopt the BMPs, whereas growers with non-financial goals (or mixed goals) were less likely to adopt a given BMP. Farmers' perceptions of the BMPs contributed to the adoption decision in a positive way. Estimates indicate that growers who perceived the BMP as a better alternative than their current practice or technology were more likely to adopt the BMP. Using M1, one can calculate the chance of adopting a BMP for a farmer with no farming experience, farming goals, which are not exclusively financial, and with the perception that the proposed BMP is a better alternative than the current water management system that they

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[22] The quality of a model to explain a phenomena or outcome variable with fewest predictors.

[23] A model is considered nested in another if the first model can be generated by imposing restrictions on the parameters of the second, where the restriction is that the parameter is equal to zero, accomplished by removing the predictor variables from the model.

are using now. Those results will be contrasted with the changes of adopting this BMP if the farmer has the same characteristics as above, no experience and mixed farming goals, and with a perception that the proposed BMP is not a better alternative. It was found that the chances of adopting a BMP in the first situation, where farmers see the BMP as a better alternative, were 89%, which was reduced to 48% if the farmer did not perceive the BMP as a better alternative.

For the second model (M2), estimated coefficients suggest that more specialized growers (those with a higher share of land cultivated with the study crop -- tomatoes, cranberries or onions) and with a higher share of sales coming from these crops, were more likely to adopt the proposed BMPs. Furthermore, growers with higher educational attainment were also more likely to adopt. Based on M2 results the chances of adopting a BMP were calculated, for a farmer with average crop size and crop sales share and high level of education attained. Those results were contrasted with the changes of adopting this BMP if the farmer has the same characteristics as above, average crop size and sales share and low level of education attained. The chances of adopting a BMP in the first situation, where farmers have high levels of education, were estimated to be 70%, but if farmers had low education levels, chances of adoption decrease to 65%.

The third model outperformed the other two on several fit statistics. Estimated coefficients for the third model (M3) show that multiple factors contribute significantly to explaining adoption behavior. Similar to previous models, a specialized grower, with higher education, who also perceives the BMP to be a better alternative, and whose farming goals are mainly financial ones, is more likely to adopt the proposed BMPs. All coefficients associated with this model are presented in Table 6.6.

Compared to M1, the independent variable BETTER has a smaller effect on decision in M3. Also noticeable is the weight EDUCATION plays in adoption decisions in the third model. Furthermore, based on the three models developed, one can observe that different socio-demographical factors can explain adoption reasonably well. However, it is the third model that seems to have an improved performance of the adoption decision by producers. The distinction between the first two models and the third one consists in the fact that the latter model contained farm, farmer, and BMP related characteristics. In addition, a notable finding was the fact that with a simple model (such as the one containing only the factor BETTER), over 25% of the variance in the ADOPT variable can be explained. In the following part of this chapter, evaluation of what factors contribute to a farmers’ perception of a BMP are described.

The previously fitted models, explain adoption of multiple BMPs, as opposed to showing factors contributing to the adoption of a specific BMP. The initial design of this study involved fitting three distinct models, for each one of the improved water management system investigated. However, due to the small sample size, this was not feasible. One might consider adding variables related to crop type in this model to be appropriate, as a proxy to the adopted BMP. Although relevant in the context of this study, this variable was not incorporated for several reasons: (i) the variables currently included in the model explain better the outcome variable; (ii) the interest was to incorporate variables derived from our theoretical framework, in order to understand their effect on adoption. This is left for future studies in this area.

6.8.2 Determinants of BMP Perception

This section focuses on identifying the determinants of farmer's perception of the relative advantage of improved water management BMPs, using data from a survey of 70 fruit and vegetable growers in Ontario and Québec. Based on an ordered logit regression model farmer's past behaviour, their farming goals, BMP's perceived characteristics, farm characteristics and economic context variables, were hypothesized to influence farmer's perception of a given BMP. The model variables are shown in Table 6.6.

Table 6.6. Description of Variables in the Ordered Logistic Model

Acronym	**Description**
BETTER	Perception of BMP as a better alternative than current practice
GOALS	Farming related goals
EXPERIENCE	Years of farming experience
EDUC	Farmer’s level of education
EXPENSIVE	Agreement level with the statement: in the context of your farm the BMP could be expensive
SOCIETY	Agreement level with the statement: In the context of your farm the BMP could benefit society
SALES	Farm’s sales
BESTUSE	Agreement level with the statement: making best use of scarce resources is important
WATER USE	Agreement level with the statement: reducing water use in agriculture is important

6.8.2.1 Model Specification

The data used for the estimation of this model were based on the questions in the agricultural producers' survey. Respondents were asked to state the level of agreement with the statement: "In the context of your farm the improved water management system could be a better alternative than the current one". Responses were coded as: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree and 5=Strongly Agree. These categories were further collapsed into three: -1=Strongly Disagree and Disagree, 0=Neutral and 1=Agree and Strongly Agree. These measurements were saved under the ordered categorical variable entitled BETTER. The probability model was specified as shown in equation 6.6.

$$\text{BETTER} = \beta_0 + \beta_1 GOALS + \beta_2 EDUC + \beta_3 EXPERIENCE + \beta_4 EXPENSIVE + \beta_5 SOCIETY + \beta_6 SALES + \beta_7 BESTUSE * WATERUSE + \varepsilon_i \quad (6.6)$$

6.8.2.2 Model Evaluation

Based on the model fitting information, log likelihood of the full model is -29.59. Compared to that of r the null model (one that contains only the intercept) of -67.52. This led to the rejection of the hypothesis that all of the regression coefficients in the model are zero, at the p-value < 0.001. Several pseudo-squared values were also estimated to evaluate the power of explanation of the model. These included Cox and Snell = 0.66, Nagelkerke/Cragg & Uhler's = 0.74, and McFadden's pseudo R^2 = 0.56, which indicate that the model explains somewhere between 56% to 74% of the outcome variable.

The estimated model is presented in Table 6.7, where a summary of the results along with parameter log odds estimates for the ordered logistic regression model for factors influencing fruit and vegetable growers' perception of relative advantage in Ontario and Québec are presented.

Based on the developed model, several variables had a negative influence on farmers' perception of the BMP as being a better alternative. Farmers without exclusive financial farming goals were less likely to find the BMP alternative as a better one. Like this variable, farmers with a higher level of education or more experience was less likely to see the proposed BMP as a better alternative. Farmers, who perceived the BMP as expensive were also less likely to perceive the BMP as a better alternative.

Table 6.7. Parameter Log Odds Estimates for the Ordered Logistic Regression Model for Factors Influencing Fruit and Vegetable Growers' Perception of Relative Advantage in Ontario and Québec

Variable	***Coefficient (log odds)***	***S.E.***	***Significance (p-value)***	***Confidence interval (lower)***	***Confidence interval (upper)***
Goals	-2.67	0.96	0.01	-4.54	-0.80
Education	-1.84	0.73	0.01	-3.27	-0.40
Experience	-0.08	0.04	0.05	-0.15	-0.00
Expensive	-2.83	0.89	0.01	-4.57	-1.10
Society	2.63	0.71	0.01	1.26	4.00
Sales	5.01	1.76	0.01	1.57	8.45
*Best Use*Water Use*	0.23	0.09	0.01	0.06	0.41

There were also three factors that influenced perception of the BMP in a positive way. Farmers, perceiving the BMP as providing benefits to society, were more likely to perceive the practice as a better alternative. In addition, respondents gaining a larger percentage of their revenue from the crop of interest were more likely to see the proposed water management system as a better alternative. Furthermore, growers who think making best use of scarce resources is important and believe the proposed BMP reduces water use on their farm, are more likely to perceive the BMP as a better alternative.

In addition to reporting the log odds parameter estimates, marginal effects estimates were calculated and summarized in Table 6.8. A change in goals from financial to a higher order goal triggers a negative effect on the perception of the BMP, with the farmer being approximately 41% less likely to perceive the BMP as a better alternative. In other words, a farmer whose goals are not solely financial is less likely to perceive the BMP as being a better option. Results also suggest that if the level of education is increased by one unit, the respondent is 28% less likely to perceive the BMP as better, however this results was contrary to the expected one – as education increases so does the likelihood of perceiving the BMP as a better alternative. In addition, an increase of one unit in the farmer's experience will decrease the better perception of the BMP by nearly 1.2%.

As previously mentioned, some factors also had a positive effect on the BMPs perception. An increase in the perception of the farmer that the BMP will benefit society as a whole increased the chance of a better perception of the BMP by over 40%. A 1% increase in the proportion of sales coming from either tomatoes, cranberries or onions (depending on the agricultural system of interest), increases the likelihood of producers perceiving the BMP as a better alternative by nearly 77%. Farmers are 3.6% more likely to perceive the BMP as a better alternative, if it results in best use of scarce resources together with the belief that the proposed BMP will reduce water use.

Table 6.8. Parameter Marginal Effects Estimates for the Ordered Logistic Regression Model for Factors Influencing Fruit and Vegetable Growers' Perception of Relative Advantage in Ontario and Québec

Variable	***Coefficient (B)***	***S.E.***	***Significance (p-value)***	***Confidence interval (lower)***	***Confidence interval (upper)***
Goals	-0.41	0.15	0.01	-0.70	-0.17
Education	-0.28	0.14	0.03	-0.55	-0.02
Experience	-0.01	0.01	0.06	-0.02	0.001
Expensive	-0.43	0.12	0.01	-0.68	-0.19
Society	0.40	0.15	0.01	0.11	0.69
Sales	0.77	0.28	0.01	0.21	1.33
*Best Use*Water Use*	0.04	0.02	0.04	0.002	0.07

6.9 SUMMARY RESULTS AND DISCUSSION

Our findings indicate that surveyed farmers were equally divided in terms of their decision to adopt the proposed BMPs. When compared to non-adopters, adopters had attained higher education levels, had a higher share of income coming from agricultural activities and had less faming experience. Adopters also had a higher share of sales coming from the study crop (tomato, cranberry or onion production) and owned a higher share of their farmed land than non-adopters own.

Adopters were asked about the main factors influencing their adoption decision. Respondents indicated that the most important factor was the BMP's capacity to increase yields, followed by the profitability of investment and ability to undertake trials of the said technology.

In addition to these factors, adopters also found important non-financial factors, like demonstrating environmental stewardship, an important factor affecting their decision to adopt.

Non-adopters were asked about the factors that were important in their decision not to adopt the BMPs. The main factors identified, in the order of their importance, were market stability, profitability of investment, initial cost of the system and the risk of investment. Non-adopters were also asked about policy changes that would change their views on adoption. Producers not willing to adopt the new water management system expressed that an increase in the share of the total cost of the investment supported by the government for these systems, together with increased governmental technical assistance and tax credits, would affect their decision about the adoption of the BMP. Approximately half of non-adopters also indicated that an increase in water costs might change their views on adoption.

Respondents were asked about their perceptions related to the proposed BMPs. A large majority of farmers perceived the BMPs as being profitable, yet expensive, capable of improving crop yields and having the potential to reduce water use on their farms. Related to BMPs perceptions, several differences were identified between adopters and non-adopters. When compared to non-adopters, adopters perceived the BMPs as better alternatives than their current water management systems. Furthermore, more adopters perceived the BMPs as profitable, having the potential to reduce fertilizer or chemical run-off and less adopters found the BMPs expensive, when compared to non-adopters.

Respondents were also asked about perceived barriers to the adoption process. The majority of farmers indicated that the initial cost of the system, low prices and profit margins together with lack of market stability as main barriers to adoption. Adopters reported more frequently than non-adopters that availability of capital investment was an important barrier in the adoption of the BMP compared to non-adopters. Adopters also tended to be less neutral than non-adopters about availability of funds being a limiting factor in adoption. Statistically significant differences between the two groups existed as for these barriers. In addition, more adopters considered low prices and low profit margins as an important potential barrier, in comparison with the non-adopters.

On perceptions regarding farmers' environmental responsibilities, respondents indicated that making best use of resources was important to them, together with reducing water use and

GHG emissions coming from agriculture. They also agreed that farmers should be responsible for minimizing environmental damages coming from their farm; however, only few believed farmers should be the only ones supporting the costs associated with environmental damages because of their farming operations. In addition, most farmers agree with the statement that society should share the costs of minimizing agriculture's impact on the environment. A large majority of farmers agreed with the statement that cost-share programs, supporting the adoption of improved agricultural practices and technologies, represent good usage of public funds.

Farmers' perceptions of the BMP as a better alternative was positively associated with finding the BMP profitable, capable of increasing crop yields, reducing GHG emissions, reducing water use, as well as fertilizer and chemical run-off from their farms. In addition, perception of the BMP as having a relative advantage was positively associated with it benefiting the local community and society at large. Perceiving the BMP as being expensive was negatively correlated with the BMP being seen as a better alternative.

Three regression models were estimated to understand the role played by factors in influencing adoption behavior. Assessing the models using goodness of fit statistics, the model containing a mix of socio-demographic attributes, together with farmers' perceptions about the BMP, explained the outcome of adoption the best. Study results show that a specialized grower, with higher education, who also perceives the BMP as a better alternative, and whose farming goals are mainly financial ones, is more likely to adopt the proposed BMPs. The likelihood of adopting the proposed BMPs can be explained relatively well by the three different combinations of factors. However, the models that best explain variations in likelihood of adoption contains a mixture of farm, farmer and BMP related variables. When evaluated individually for factors, the one related to BETTER (meaning the degree to which a BMP is being perceived as a better alternative), explained most of the outcome for the variable ADOPT.

Farmers' perceptions of BMPs characteristics are key factors in adoption decisions. Given that one of the most important characteristics of a BMP in the adoption process is whether farmers perceive the BMP as a better alternative than the current practice, this variable was used as an outcome variable in understanding what influences perceptions. While certain variables remained the same as in the adoption model, some of them were different. Based on the estimated model, several variables had a negative influence on farmers' perception of the BMP as being a better alternative. With higher order goals, farmers were less likely to find the alternative as a better one. Like this finding, farmers with a higher level of education were less likely to see the proposed BMP as a better alternative. Respondents with more experience were also less likely to perceive the BMP as a better alternative. Farmers, who perceived the BMP as expensive were estimated to assign a lower likelihood of the BMP being a better alternative. There were also three factors that influenced perception of the BMP in a positive way. (i) Farmers perceiving the BMP as providing benefits to society were more likely to perceive the practice as a better alternative. (ii) The respondents obtaining a larger percentage of their revenue from the crop of interest were more likely to see the proposed water management system as a better alternative. (iii) The growers who think making best use of scarce resources is important and believe the proposed BMP reduces water use on their farm, were more likely to perceive the BMP as a better alternative.

Our findings are in line with previous research, which show differences in education, farming experience, farming goals and degree of farm specialization between adopters and non-adopters can influence adoption decisions. An interesting finding, contrary to existing knowledge, was that there was no association between farmers past adoption behavior and future intentions of adopting a BMP. In terms of motivations for adopting or reasons for non-adopting improved water management systems, a large majority of factors are related to the financial effect of the BMP on the farm. This observation is also supported by previous literature (Baumgart-Getz et al., 2012; Feder and Umali, 1993; Knowler and Bradshaw, 2007; Lamba et al., 2009; Pannell et al., 2006; Prokopy et al., 2008). Furthermore, this study showed that perceiving a BMP as a better alternative is positively associated primarily with adoption and the innovation's capacity to benefit the farmer financially. Positive environmental and societal effects of the BMP (i.e., GHG emissions reduction) were also relevant factors that contributed to farmers perceiving the innovation as a better alternative. However, these non-financial factors did not influence farmers' decisions to adopt a BMP. Perceiving the BMP as a better alternative was statistically significant across two of the three groups of surveyed producers – tomato and cranberry growers. Our assumption is that this is due to two important factors in adoption decisions -- commodity grown and BMPs characteristics.

CHAPTER 7. SUMMARY AND CONCLUSIONS

7.1 SUMMARY

Climate change is expected to impact high value horticultural production taking place in Eastern Canada. Growers in Southern Ontario and Québec rely on irrigation and drainage practices to ensure their successful production. However, due to climate change, resulting in diminished soil moisture, increased frequency of extreme events (Romero-Lankao et al., 2014), and competing uses from other users in the region, availability of this resources may be limited. Furthermore, Canada committed itself internationally to reduce its GHG emissions by 30% by 2030 (Environment and Climate Change Canada, 2018). Through research funding (Global Research Alliance, 2018) the and cost-share programs (AAFC, 2014b), the country is evaluating solutions to both mitigate GHG emissions coming from agriculture, and to support increased resilience of farms considering these changes to come. On-farm mitigation and adaptation strategies have been recognized as important measures to help the country move towards meeting its goals related to GHG emissions, and in safeguarding the livelihoods of agricultural producers in the face of changing climatic conditions.

This study was designed with the purview of above broader context. Building on existing literature, this study aimed at filling certain research gaps. Namely, it was interested in understanding social, economic and environmental effects of improved water management practices and technologies in the context of Canadian fruit and vegetable production. Furthermore, this study aimed to contribute to the adoption of agricultural innovation literature selecting factors that foster or limit adoption of BMPs, together with building on the discussion on importance of technology (BMP) characteristics in the adoption process. These aims are further reflected in the two main research objectives of this research.

(1) The first objective was to quantify and evaluate farm level effects associated with the adoption of three improved water management practices and technologies, by looking at their adoption on three case study farms – tomato, cranberry, onions, located in Leamington Ontario and Saint-Louis-de-Blandford and Saint-Patrice-de-Sherrington, Québec.

(2) The second objective was to identify main reasons for adoption, barriers to adoption and other relevant factors in the process of adopting proposed beneficial water management practices and technologies, as seen from the perspective of regional growers. In addition, a subobjective was to identify the role played by perception on adoption of BMPs.

This study evaluated different irrigation and drainage practices (called BMPs) within the context of above noted three farms by comparing the situation when the BMP was adopted and that when it was not. The former situation was called BMP scenario while latter situation the baseline scenario, which reflected the status quo technology. To evaluate the financial desirability of investments, production budgets were developed for each one of the scenarios. Results were converted into two indicators – net present value (NPV) and benefit-cost ratio (BCR), in order to assess the financial desirability of investments.

The first farm was in Leamington, Ontario. On this farm tomato for processing were grown in field, using two irrigation systems. The baseline technology was surface drip irrigation and subsurface drip irrigation for the alternative scenario. The second case study was in Saint-Louis-de-Blandford, Centre-du-Québec, Québec, which was a cranberry farm. The baseline scenario involved a water management system that kept the water table relatively high. This was compared to the alternative scenario, in which water table levels were lowered and monitored with the use of tensiometers. The last case study, located in Saint-Patrice-de-Sherrington, Montérégie, Québec, was an onion and carrots production farm. The baseline scenario in this case study was dryland production, whereas the alternative scenario looked at production under sprinkler irrigation. Beyond economic effects, available literature was used to evaluate social and environmental effects. To ensure robustness of the financial feasibility analyses, sensitivity analyses were conducted, to estimate the impact on profitability of variability in factors like, crop prices, yields, and cost of investment, farm size and discount rates.

This study also identifies important factors associated with adoption of improved water management systems / practices / and technologies by fruit and vegetable growers in Ontario and Québec, Eastern Canada. A survey approach was used to collect responses from regional growers in relation to the proposed BMPs, which were studied in the context of the three farms. Tomato, cranberry and onion producers were contacted and their likelihood to adopting the proposed BMPs were inquired, along with their opinions and perceptions of the BMPs, as well as questions related to their attitudes towards their role as stewards of the environment. Method of analysis of these responses included summary statistics, and correlation tests. Furthermore, regression models (logistic regression and ordered logistic regression models) were built to evaluate important factors leading to producer's decision to adopt the BMP, including their perception of the BMPs.

7.2 CONCLUSIONS

Within the context of the three case studies, results of farm level analyses indicated that the proposed improved water management practices and technologies (BMPs) were more profitable, when compared to baseline technologies and practices. Even when key parameters were varied (in a sensitivity analysis framework), results were consistent in favor of the BMP. Thus, in two of the three cases, the proposed BMP was identified as a better and a financially desirable solution. The exception was the sprinkler irrigation system in the context of the onions and carrots agricultural production system, which is sensitive to commodity price drops and yields increase. The sensitivity analyses also indicated that there are reasons to cautiously expand the applicability of these findings to smaller agricultural production systems, particularly under different market conditions (i.e., diminished commodity prices), or even different climatic conditions in the case of cranberry farms (i.e., more or less rainfall than the season average), or for growers with different risk attitudes (i.e., discount rates).

While there is more certainty over the reliability of findings related to the financial feasibility of adopting these proposed BMPs, it is less clear what the environmental and social effects of these improved water management systems are. While data from secondary resources indicated that these alternative practices and technologies have the capacity to reduce water use, energy use, reduce GHG emissions and improve nutrient use efficiency, these findings have more uncertainty in the context of the studied farms. This was created by a lack of statistically significant results for GHG emissions. A possible reason for this uncertainty might be the short period of observations -- data were collected only over two growing seasons, and the large variability across sampled GHG emission data. However, other studies (although in slightly different experimental set up[24]) showed a marked improved in environmental indicators (water use efficiency, GHG emissions and labor requirements for production activities).

In terms of social effects, the results were mixed, with some BMPs increasing hired labor needs, while others did not. Furthermore, all proposed BMPs required more involvement of the producer for decision-making and related activities, which could potentially reduce the availability of spare time for leisure.

Financial analyses on the three case study farms were practical solutions – in lieu of representative farms, which allowed the comparison of a status quo water management system to an alternative. They were a practical solution to the initial proposed approach that involved surveying a large sample of farms in each one of the regions. Analyses of the three case studies were intended as exploratory studies, the first stage of an ongoing longer-term research project, within the Agricultural Greenhouse Gases Program. This research contributes to the broader research, by helping to inform the development of representative farm models for the studied commodities, within the study areas. This research can be used as a building block for future studies involving more complex stochastic models. In terms of contribution to direct application, even though broad generalization of results to the entire population of tomato, cranberry and onion growers in Ontario and Québec is not possible, this research provides transferable knowledge to other large farms in these regions, which have similar cultural practices and biophysical conditions**.**

The second major objective of this study was to understand regional growers' views on the proposed BMPs and the influence of different factors in their intention to adopt the improved water management systems. There were 70 growers who completed the survey – 39 tomato growers, 19 cranberry growers and 12 onion farmers. The study results showed that half of the sampled farmers were in favor of adopting the BMP, whereas the other half were not. However, when different farm groups analyzed, majority of onion growers were interested in the proposed BMP, cranberry producers were also predominately in favor of adopting subirrigation, whereas tomato growers were not interested in adopting a subsurface drip irrigation system. When compared to non-adopters, adopters had attained higher education levels, had a higher share of income coming from agricultural activities, and had less faming experience and primarily financial goals from farming.

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[24] As an example, nutrient use efficiency for tomato irrigation was done under an experiment that included fertigation, which can have an impact on overall results.

Adopters also had a higher share of sales coming from the selected crop (tomato, cranberry or onion) and owned a higher share of their farmed land than non-adopters own.

A BMP was perceived by producers as a better alternative if it provides an added economic benefit, as well as reduced a cost or added benefits the local and global community. Farmers perceived the proposed BMPs as being profitable, but expensive, capable of improving crop yields and having the potential to reduce water use on their farms. Related to BMPs perceptions, several differences were identified between adopters and non-adopters. When compared to non-adopters, adopters perceived the BMPs as a better alternative than their current water management systems. BMPs are perceived as better alternatives if they are profitable, capable of increasing crop yields, reducing GHG emissions, reducing water use, fertilizer and chemical run-off from their farms, and benefiting the local community and society at large.

Economic factors predominantly influenced decisions of producers for adoption of the BMPs. Among these, influencing factors included BMP's capacity to increase yields, the profitability of investment, and ability to perform a trial of the technology. In addition to these factors, adopters also found non-financial factors like demonstrating environmental stewardship, important. Main factors identified as reasons to not adopt the BMPs, in the order of their importance were: market stability, profitability of investment, initial cost of the system, and the risk of investment.

Producers were also asked what type of economic incentives might be able to help then in encouraging BMP adoption decisions. Producers not willing to adopt the new water management systems thought that an increase in the share supported by the government for these systems, together with increased governmental technical assistance and tax credits were important in changing their opinion towards adoption. Approximately half of non-adopters also indicated that an increase in water use costs might change their views on adoption.

Farmers see themselves as having to bear certain environmental responsibilities including making best use of resources, reducing water use, and GHG emissions coming from agriculture, and thereby responsible for minimizing environmental damages caused by their farm. However, only few believe that farmers should be the only ones supporting these costs associated with environmental damages from their farming activities. Most farmers agreed that society should share the costs of minimizing agriculture's impact on the environment. Furthermore, farmers believe that cost-share programs, supporting the adoption of improved agricultural practices and technologies, represent good usage of public funds.

The likelihood of adopting the proposed BMPs can be explained relatively well by different combinations of factors. Based on this study, the models, which best explain variations in likelihood of adoption should contain a mixture of farm, farmer and BMP characteristics related factors. Producers' perception that a BMP is better than the one they are currently using (degree to which a BMP is being perceived as a better alternative), explained most of the adoption outcomes (Variable ADOPT). A specialized grower, with higher education, who also perceived the BMP as a better alternative, and whose farming goals were mainly financial ones, was indicated to more likely adopt the proposed BMPs.

Given that one of the most important characteristics of a BMP in the adoption process is whether farmers perceive the BMP as a better alternative than the current practice, factors affecting this variable were identified using an ordered logistic function. Farmers with higher order farming goals (financial and lifestyle or social goals) and with higher education levels were less likely to find the alternative better than their current practice. Whereas, more specialized farmers perceiving the BMP as providing benefits to society, and who thought that making best use of scarce resources is important, along with the belief that the proposed BMP would reduce water use on their farm, were more likely to perceive the practice as a better alternative.

These study findings are in line with previous research, which has shown that differences in education, farming experience, farming goals and degree of farm specialization between adopters and non-adopters are significant factors for adoption of a BMP. An interesting finding, contrary to expectations, was that there was no association found between farmers past adoption behavior and future intentions of adopting a BMP. In terms of motivations for adopting or reasons for non-adopting improved water management systems, a large majority of factors are related to the financial effect of the BMP on the farm. This observation is also supported by studies by Baumgart-Getz et al. (2012; Feder and Umali (1993; Knowler and Bradshaw (2007); Lamba et al. (2009); Pannell et al. (2006) and Prokopy et al. (2008). Furthermore, this study has shown that perceiving a BMP as a better alternative is positively associated with adoption and the innovation's capacity to benefit the farmer financially. Positive environmental and societal effects of the BMP (i.e., GHG emissions reduction) were also relevant factors that contributed to farmers perceiving the BMP as a better alternative. However, these non-financial factors did not affect farmers' decisions to adopt a BMP. Perceiving the BMP as a better alternative was statistically significant across two of the three groups of surveyed producers – tomato and cranberry growers. One may hypothesize that this could be due to two important factors in adoption decisions - commodity grown and BMPs characteristics.

7.3 LIMITATIONS

This study has several limitations, need to be acknowledged, as they are important paths to pursue in future research avenues in this area.

(1) Farm level analyses, case studies and generalization of results

The farm level analyses were conducted using three case study farms. Results cannot be generalized to the entire population of tomato, cranberry or onion growers in Ontario and Québec. However, they can be used to provide insights for similar cases – large producers, within the studies regions – Essex County, Ontario (for tomatoes), Centre-du-Québec and Montérégie (for cranberry and onions). However, in transferring knowledge to other farms, even within the region, proper attention needs to be paid to the biophysical characteristics of the case studies farms (i.e., in terms of type of soil, water source, among others), other factors related to the farm's cultural practices (i.e., crop rotation followed), overall economic characteristics of the studied farm, and characteristics of water management systems (i.e., original layout of a drainage system, gravitational in-field water supply).

(2) Farm level analyses, deterministic models and reliability of findings

Even though important factors that were considered to influence profitability of the investment, these factors were analyzed in a disaggregate way (one change at a time). In reality, one may visualize situations where multiple factors may change at the same time. Moreover, deterministic models like the ones used in this study do neither account for risks and uncertainties related to variation in market prices for inputs or outputs, nor do they account for variability in climatic conditions; both are highly relevant to agricultural production systems. Furthermore, modeling the impact of changes to farm economics using a deterministic model can eventually result in an overestimation of the effects of the change on the farm's economics (Robertson et al., 2012). But Thornley and France (2007) have mentioned that deterministic models could be a useful first step in performing analyses, and that once developed, can be assessed to determine the need for additional stochastic modelling.

(3) Regional growers survey and generalization of results

A small non-random sample size does not allow for generalization of results to the entire population. Findings are usually treated as evidence that pertains to the specific sample data collected. However, with proper triangulation methods in place, it is possible to use these findings outside the boundaries of the initial sample.

(4) Regional growers survey and reliability of results

As previously noted, the findings of this study were based on a small and non-random sample of growers. These facts bring forward three challenges for our results' integrity and their wide applicability. The first challenge is related to the statistical power of our findings and the increased chance of introducing a type II error due to our small sized sample, in the case of this analysis, one may run the risk of finding association effects that are not there. Given that collecting a larger sample of respondents was not feasible, one must mitigate against this potential problem by double-checking the findings with already published work, and refrain from drawing strong conclusions from these findings.

The second challenge is related to the non-random sample frame used for this research. The choice of this sampling method was merely a compromise, and it was due to limited capacity of recruiting respondents. While an effort was made to reach out to as many producers as possible – flyers posted online, research presented in regional newsletters, in growers' annual meetings, etc., more reliance was given to the contact information provided by local experts or members of growers' associations and government extension officers. A non-random sample, while helpful as a practical solution and for explorative purposes, especially for pilot studies, it has several limitations. These limitations include sample bias, diminished reliability of findings and lack of being able to generalize results. Some issues can be mitigated by triangulating results using already published work and experts' opinions, while other limitations, like the issue of generalizability of results cannot.

Lastly, the third issue, which also stems from the fact that the sample size was small, is the fact that this study was not able to look independently, at each one of the three growers' groups – tomato, cranberry and onion producers. This approach would have been desired, especially given the statistically significant difference between these three groups relating to willingness of adoption.

7.4 POLICY IMPLICATIONS

The BMPs selected for this study were hypothesized as means of reducing environmental impacts (i.e., reduction in GHG emissions, improve water use efficiency, etc.) of agricultural production systems, while being financially viable for agricultural producers. In deciding which policy responses are most appropriate, it is important to understand the balance between on and off farm net benefits, from a financial and environmental perspective.

Based on the three case studies used in this research, one may note that all proposed BMPs were financially viable options. Other producers whom were interviewed also supported these results. Approximately 80% of the surveyed producers agreed that the proposed BMPs were profitable. Furthermore, 57% of them also agreed that in the context of their farms, the BMP would increase yields, reduce production risks, reduce water use and represent a better alternative than their current practice. However, they mentioned that they found the proposed BMP expensive, and identified some challenges that preclude them from adopting these practices and technologies on their farms. Some of the most commonly identified barriers were the initial cost of the BMP, capital availability needed to make the investment, and market instability. Perceiving the proposed BMPs as a better alternative than the status quo technology or practices used by producers on their farms, represented one of the most important factors, which explained producers' adoption decisions. Surveyed producers indicated that certain policy responses would enable them to reconsider adopting the proposed BMPs. The most popular policy response among respondents was an increase of 30-50% of the BMP cost-share supported by the government, followed by increase in technical assistance and information related to these BMPs. Tax credits on investment and increase of water costs, by an average rate of 18%, did a smaller group of respondents endorse policy responses.

In terms of the environmental effects of the three proposed BMPs, there is not sufficient evidence to understand if the BMPs bring additional benefits or not. In terms of GHG emission levels, even though the proposed BMPs had on average lower emissions over two growing seasons, compared to the status quo practices and technologies, these differences were not statistically significant, as measured and analyzed by Edwards (2014), Grant (2014) and Lloyd (2016). However, in all cases under the proposed BMPs the GHG emission balance was positive, varying from 0.57 CO_2-eq t/acre in cranberries, to 0.74 CO_2-eq t/acre in onions, and 2.32 CO_2-eq t/acre in tomatoes. Given that an average cranberry farm cultivates 400 acres, and a carbon cost of $20/t, an average cranberry farm produces an annual negative externality of $4,560. An average onion farm has 15 acres under cultivation, their annual average negative externality adds up to $222, whereas for the average tomato farm the average externality is somewhere between $1,000 and $1,500 on an annual basis. These costs are likely to increase five times by 2022, as the Canadian government plans to increase the carbon tax to $50/t.

Given the potential role of these technologies and practices to reduce GHG emission levels, and subsequently to reduce these costs for the global society, it is important to study them in more depth, over a longer period of time and over a broader geographic area and farm types, the effect of improved water management systems on GHG emission levels. Under these circumstances one of the first policy recommendations involves making use of various advisory and information sharing instruments, such as research and development, technical assistance, and good communication of research and findings. It is also important to communicate to producers about linkages between water use efficiency and GHG emissions and about BMPs that have already been shown to reduce these emissions efficiently. Extension programs and officers need to focus on the added benefits brought forward by the proposed BMPs; they need to highlight its relative advantage compared to the status quo technology and practice. Furthermore, the need for technical assistance was also identified by surveyed producers as an important factor contributing to their decision to adopt a BMP, as was the ability to trial the technology.

Besides advisory and communication policy responses, some economic instruments can also be considered. One mechanism of eliminating these negative externalities is to reflect these costs in the price of the crop. This transfers the cost of these externalities to consumers. However, this would not represent an ideal situation, because producers would not be incentivized to find solutions for GHG reduction, also unrealistic, since producers are more often in the position of a price taker in the market, as opposed to them dictating prices. An economic policy response to this issue could be the introduction of a carbon tax, which in return would give the producers some flexibility in addressing these externalities. However, given the political apprehension to propose such a measure, together with the historical precedent in agricultural policies to not use the "polluter pays" principle, but rather the "beneficiary pays" principle, this type of policy responses might be difficult to champion and to be accepted.

Given the positive correlation between increased water use efficiency and GHG emission reduction, another policy instrument can be used to change farmers' behaviour. An increase in water costs can be an effective way of encouraging farmers to conserve water. As previously indicated, a small percentage (35%) of surveyed farmers believed that an increase in water costs would change their opinion about adopting the proposed improved water management systems. Our recommendation includes a mix of responses, starting with moral suasion and communication about the importance of water conservation, and the important role played by highly efficient water management systems in adapting to new climate conditions. This policy intervention can then be followed by a subsequent increase in water costs, using an increasing block pricing system.

Another policy response endorsed by majority of producers who answered the survey was an increase in the cost-share support provided by the government. Taking into consideration the financial feasibility of the proposed BMPs, one could argue that since the investment is self-sustainable, there is no need for any governmental intervention beyond communication. However, the case for government assistance under the form of cost-share programs can be motivated by the need to speed up the diffusion of these agricultural innovations. Canada has committed internationally to reducing 517 Mt CO_2-eq. by 2030. Agricultural cost-share programs are part of the set of tools used to reach this target. For this policy instrument to be cost-effective, it requires better targeting of agricultural producers with large externalities, and funds allocated based on the environmental performance of the BMPs, as previously suggested by other scholars (Baird, 2012; Engel et al., 2008).

Lastly, there are also several practical policy recommendations for future data collection that are listed below:

- Development of regional cost of production benchmarks for tomato, cranberry and onion production in Ontario and Québec;
- Development of a public research Canadian agricultural database containing farm level economic, biophysical data for different regions, different agricultural production systems, and varied water management practices;
- Development and maintenance of a panel of agricultural producers with different specializations, which can be used by researchers in a fee-for–service regime, and where producers can be remunerated for providing information (i.e., EKOS Probit Probability Based Panel[25]). One of the biggest challenges in researching the social aspects of agricultural production is data collection from agricultural producers. A solution like the one proposed above, can help incentivize an agricultural producer (at least offset the time spent filling in a questionnaire), and would give researcher easier access to the groups of interest.

7.5 AREAS FOR FUTURE RESEARCH

Taking into consideration the existing literature, our findings together with our limitations the following areas for future research are proposed:

- Research on long term effects of proposed improved water management practices on GHG emissions levels, water use, nutrient use, energy use and soil productivity, crop yields, crop quality, and other relevant biophysical and economic indicators;

[25] "…panels are probability-based; where all members are recruited via random digit dial (RDD) methodology. The fundamental requirement of this methodology is that every member of the population has an equal and known chance of being invited to join the panel and later (once they are members of the panel) of being invited to do a survey. This methodology offers the most efficient and effective way to collect data that can be accurately projected to the total Canadian population and support scientific testing and error estimate." EKOS (2019)

- Studying and building representative farm models, which can be used to estimate regional impact of adoption of the selected BMP by producers. Being able to quantify the regional effects of BMP adoption, is important for policy purposes, as it can inform which agricultural projects should be prioritized.
- Further research on the relation between perception of BMP characteristics and its effect on adoption. While a first attempt was made here and elsewhere to show the importance of perception on behavior, few things can be further pursued. First, it is important to take a rigorous approach to collecting data for each one of the constructs that explain adoption – attitude towards behavior, subjective norms, etc. Standardized ways of building a survey to this end exist already. Furthermore, one can use different analytical tools to explain adoption within this theoretical framework, approaches that take into consideration causality and take into consideration sets of constructs (i.e., structural equation modelling).
- In future studies, one may consider adding variables related to crop type. This might yield a better estimate for different types of farms. One may suspect that due to large number of tomatoes producer, the estimated coefficients may be reflecting more of these producers.
- Theoretically, one may postulate that the perception of the adopter for a given technology might be instrumental in affecting its adoption. Inclusion of this variable in the model explaining adoption might consider using such an approach.
- Although relevant in the context of this study, these variables were not incorporated for several reasons: (i) the variables currently included in the model explain better the outcome variable (ii) the interest was to incorporate variables derived from our theoretical framework, in order to understand their effect on adoption, and lastly (iii) the recommended change while not extensive, it would have triggered many changes in the dissertation, which would have taken me longer than two weeks to address.
- Diversified methodological approaches in understanding adoption decisions and their diffusion, such as a mixed methods approach, where there are with focus group, a qualitative approach (with in-depth interviews), and an even experimental research approach. These methods can increase our understanding of this area of research, and potentially bring new insights. A qualitative approach can expand our knowledge of how farmers make decisions, what their business and personal priorities are, and through these

in-depth discussions, new perspective and lines of research can be developed, which are in tune with producers' needs. An experimental approach can allow us to further tease out farmers and society's willingness to pay for having an improved agricultural production sector. This can be assessed for example through simple choice experiments.

- Use of novel analysis techniques and methodological approaches, like social network analysis, allowing for a different conceptual framing of the adoption problem, which could prove to be beneficial in finding more consistent social factors of adoption. The propagation of ideas, diffusion of innovations, organizations' patterns of interaction and its effect on adopting new practices and technologies, have been important areas of study within the field of social networks. To date, only few studies have used this approach to investigate farmers' networks and their process of adopting new practices and technologies.

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APPENDICES

Appendix A. FARM LEVEL DATA COLLECTION: SEMI-STRUCTURED INTERVIEW INSTRUMENT

University of Saskatchewan
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PART I. FARM BACKGROUND INFORMATION

1. What is the total size of the farm (number of cultivated acres)?
2. Do you operate a livestock enterprise on your farm?
3. If you have livestock, please provide the following details:

   Answer:

	Cattle (heads)	Dairy (heads)	Sheep (heads)	Poultry (heads)	Others (heads)
Number of breeding stock	None	None	None	None	None
Number of marketable livestock					

4. Please indicate, as well, which types of crop you currently have on your operation (if others, please specify). If there are price differences based on differences in quality please also provide the different price levels as well as the percentage of the crop corresponding to each price level.

   A. Acres under cultivation for each crop and yields levels for both irrigated and non-irrigated crops

Crop	Irrigated (acres)	Yield (tons/acre)	Non-irrigated (acres)	Yield (lbs./acre)
Tomatoes				
Seed Corn				
Wheat				
Corn				
Soybean				

   B. Percentage of crop receiving regular and premium prices and the price level differences

Crop	Regular Price (%)	Premium Price (%)	Regular Price ($/ton)	Premium Price ($/ton)
Tomatoes				
Seed Corn				
Wheat				
Corn				
Soybean				

5. Do you use a crop rotation system? If so, please provide details on the current crop rotation systems.

6. What was your crop rotation system previous to the adoption of the new irrigation system, if different than the current one?

7. How much of the farm land is: (please specify the percentage or acreages)

   - ☐ Owned
   - ☐ Rented/leased from others
   - ☐ Rented/leased to others
   - ☐ Other, please specify

8. What is the operating arrangement of the farm?

   - ☐ Sole Proprietorship
   - ☐ Corporation
   - ☐ Partnership
   - ☐ Other, please specify

9. What is your water source for irrigation purposes?

10. Do you have an Environmental Farm Plan? Please provide details as to why you have chosen that option.

PART II. ADOPTION OF IMPROVED WATER TABLE MANAGEMENT PRACTICE COSTS AND BENEFITS

1. Please, concisely describe the current irrigation management practices.
2. In which year and on what percentage of your tomato enterprise/ number of acres have you adopted the new practice?
3. Will you be receiving any financial assistance (i.e. governmental) for the new practice? Please provide details regarding the amount and the source of assistance.
4. Will the costs for the project be covered using financing?
   - ☐ Yes
   - ☐ No
5. What is your estimate regarding the useful life of this project?
6. Did you notice changes in yield and/or quality of tomato production after adopting SSDI? Please comment and provide details on the percentage of yields or quality increases.
7. Were there any other changes associated with SSDI adoption in tomato production? Please provide details on the percentage of change.
8. Are you expecting any other changes/impacts on the rest of your farm operations brought by the adoption of SSDI? Please describe them.

9. Please indicate the initial investment costs associated with the adoption of the new water table management practice.

Item Description	Total Cost ($)	Comments
SYSTEM COST – INITIAL INVESTMENT		
Materials and installation		
Drip Tape		
Drip Tape Installation		
Headers, connectors and valves		
Header Installation		
4" PVC pipeline		
Water Pump		
Water Pump Tractor		
Filter Station		
Electric Valves with Fittings		
Automation Valve		
Water reservoir		
Pipeline Ownership		
Water Withdrawal Permit		
Other Initial Investment Costs		
GPS unit		

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School of Environment and Sustainability

PART III.TOMATOES PRODUCTION COSTS

In the following section of the survey, you will be asked to provide current costs of tomato production as well as expected costs of production, as estimated to accrue with the new water table management practices that you are planning to adopt. Please provide the following details.

Item Description	Without Project ($/acre)	With Project ($/acre)
Late Fall		
Plowing		
Disking		
Bed Shaping		
Potassium Application (400-500lbs/acre)		
Rye Strips		
Mushroom Compost		
Spring		
Soil Testing		
Ripping Tomato Beds		
Herbicide Application		
Pre-seed Bed Formation		
Insecticide application		
Fertilizer and Micronutrients Application		
Final Bed Preparation		
Herbicides Application		
Summer		
Tomato Transplants		
Fertilizer and Insecticide		
Planting labor		
Planter and tractor use		
Cultivation		
Herbicides Application		
Chemicals application		
Fungicides		
Tomato Ripening		
Early Fall		
Harvester (labor, tractor use, fuel)		
Additional wagon and tractor		
Additional labor (sorting)		
Tomato Hauling		
Irrigation and Drainage		
Pumping Costs		
Fuel and/or Electricity		
Labor		
Pump Repairs and Maintenance		

Other		
Other		
Water Storage		
Reservoir Repairs and Maintenance		
Water treatment		
Other		
Other		
In field		
Sprinkler heads reinstallation		
Sprinkler Repairs		
Sprinkler Replacement		
Drainage Tiles Repairs		
Drainage Tiles Replacement		
Water table management		
Other		
Other		
Other Variable Costs		
Tomatoes Insurance		
Operating Capital Charges		
Machinery and Equipment Repairs*		
Other, please specify		
Other, please specify		
Other, please specify		
Fixed Costs		
Equipment and Buildings (capital recovery charge)		
Land		
Management		
Other overhead costs		

*Excluding the irrigation system

PART IV. MOTIVATIONS, BARRIERS & PERCEPTIONS

1. What were the main motivations for adopting a new water management practice for tomato production? Please provide the details in the box bellow.

2. What are the main barriers you envision in the adoption process, if any? Please provide the details in the box bellow.

3. Which are the main short-term and long-term goals for the farm?

Short term goals	Long term goals

PART V. PERSONAL INFORMATION

1. What is your relationship to the farm?
   - ☐ Owner
   - ☐ Manager Agronomist
   - ☐ Employee
   - ☐ Other (please specify) ____________
2. What is your age?
3. What is the highest level of education that you have completed?
   - ☐ High School
   - ☐ College
   - ☐ Technical Degree
   - ☐ Bachelor's Degree
   - ☐ Graduate or Professional Degree
4. For how many years has the farm been in operation?
5. What percentage of the farm's income comes from farming?
6. Do you belong to any agricultural organization? If yes, which one?
   - ☐ Yes, please specify
   - ☐ No
7. When information is needed regarding agricultural matters, what channels are used for obtaining it?
   - ☐ Newsletters
   - ☐ Agricultural publications
   - ☐ Social Media
   - ☐ Mobile Media
   - ☐ Colleagues/Neighbors/Peers
   - ☐ Governmental publications
   - ☐ Internet Websites
   - ☐ Books
   - ☐ Other, please specify ______________________________

PART VI. Sales, Net Worth, Assets & Liabilities

This last section of the questionnaire is important for the scope of this research. We used intervals or relative values in order to assist your response. Please be assured that the information provided here, as throughout the rest of this questionnaire, is strictly confidential.

1. What were the farm's annual gross farm sales?

☐ Less than $50,000

☐ $50,000-$99,999

☐ $100,000-$249,999

☐ $250,000-$499,999

☐ $500,000-$1,000,000

☐ Over $1,000,000

2. What percentage of your gross farm sale comes from:

☐ Tomatoes production

3. What is the farm's current net worth? Variable, link to the market price

☐ $0 or less

☐ $0-$499,999

☐ $500,000-$999,999

☐ $1,000,000-$1,499,999

☐ $1,500,000-$2,000,000

☐ Over $2,000,000

Appendix B. STRUCTURED QUESTIONNAIRES FOR REGIONAL AGRICULTURAL PRODUCERS

Water Use and Field Grown Tomatoes for Processing

Agricultural Producers Survey

Thank you for agreeing to take part in this survey! My research evaluates the effects of different water management practices and technologies on and off farm. Today I would like to ask you some questions regarding your farm, and about yourself. Also I would like to gather your opinions regarding subsurface drip irrigation in tomato growing. This survey should take 15 minutes to complete. All answers you provide will be kept confidential. If you want more details regarding my research or if you would like a copy of the report among completion, please feel free to contact me.

Please click 'Next' to begin.

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Few words on subsurface drip irrigation

As you might already know, subsurface drip irrigation is a low-pressure, low-volume system, with drip tubes placed below the soil surface at a depth of approximately 15-20 cm (depending on soil type, crop and tillage practices). Previous studies found that subsurface drip irrigation in tomato production has the following characteristics:

Characteristic	Costs and Benefits Details[1]
Capital investment cost	• 1,500-2,000 $/acre[2]
Life expectancy	• 10-15 years[3]
Tomato yields	• Increased by 8% using subsurface drip as compared to surface drip • Increased by 25% using subsurface drip as compared to sprinkler • Increased by 60% using subsurface drip as compared to non-irrigation
Annual operating costs	• Decreased annual costs by 40-45% under subsurface drip irrigation as compared to surface drip irrigation[4]
Uniform ripening	• Green tomatoes percentage reduced by 16% under subsurface drip, as compared to non-irrigation
Nutrients use	• Increased efficiency of both N and P use under drip irrigation, as compared to non-irrigation
Water use	• Increased efficiency by 32% under subsurface drip as compared to non-irrigation
Greenhouse gas emissions	• Tomatoes grown using subsurface drip irrigation have 14-18%[5] lower GHG emissions than tomatoes grown with surface drip irrigation
Other	• Less labor needed with subsurface drip when compared to surface drip • More specialized machinery implements for subsurface drip in comparison to surface drip • Increased managerial decision making • Increases field accessibility • Increased need for accuracy when installing the subsurface drip as opposed to surface drip, sometimes additional resources are needed (i.e. GPS)

[1] Details are only for reference; they vary depending on the characteristics of your own farm, the subsurface drip irrigation system selected, etc.
[2] The assumption is that there was no previous irrigation system in place;
[3] Based on the most expensive part to replace from the irrigation system;
[4] Based on the assumption that the subsurface drip tape is left under the ground for 3-4 years, whereas the surface drip tape removed each year.
[5] Based on a case study farm located in Leamington, Ontario

Do you grow in field tomatoes for processing?

- Yes, please specify if processed into juice, paste or peel Type here
- No

About Irrigation

Do you currently irrigate tomatoes?

- Yes, please specify the type of irrigation system used Type here
- No, skip next question

What are your main water sources for irrigation, if you irrigate?

Type here

Would you adopt a subsurface drip irrigation system for your tomato production?

- Yes
- No

About Irrigation

On what percentage of tomato production would you adopt subsurface drip irrigation?

- 100%
- 75%
- 50%
- 25%
- 10%
- Other, please specify [Type here]

How would that change in the following years, if at all?

[Type here]

Would you borrow money to cover the initial investment?

- Yes, please specify what percentage [Type here]
- No

About Subsurface Drip Irrigation

How important are the following factors in your decision to adopt subsurface drip irrigation?

	Not at all Important	Somewhat Important	Neutral	Important	Very Important
Increased tomato yields					
Increased tomato quality					
Reduced water use costs					
Reduced fertilizer costs					
Reduced labor costs					
Reduced pests					
Profitability of investment					
Reduced soil erosion and salinity					
Reduced farm run-off					
Reduced water use					
Demonstrate environmental stewardship					
Benefit the local community					
Benefit society as a whole					
Seeing others already using the technology					
Being able to trial the technology					

About Subsurface Drip Irrigation

To what degree could the following factors represent a barrier in your decision to adopt subsurface drip irrigation?

	Not at all Important	Somewhat Important	Neutral	Important	Very Important
Initial cost of the system	○	○	○	○	○
Available investment capital	○	○	○	○	○
Access to credit	○	○	○	○	○
Risk of investment	○	○	○	○	○
Low tomato prices	○	○	○	○	○
Low profit margins	○	○	○	○	○
Water availability	○	○	○	○	○
Other farm needs take precedent	○	○	○	○	○
Steep learning curve	○	○	○	○	○
Market stability (i.e. assurance of processing contracts)	○	○	○	○	○

About Subsurface Drip Irrigation

How important are the following factors in your decision to not adopt subsurface drip irrigation?

	Not at all Important	Somewhat Important	Neutral	Important	Very Important
Initial cost of the system	○	○	○	○	○
Available investment capital	○	○	○	○	○
Profitability of investment	○	○	○	○	○
Risk of investment	○	○	○	○	○
Low tomato prices	○	○	○	○	○
Low profit margins	○	○	○	○	○
Insufficient governmental financial support	○	○	○	○	○
Insufficient information on subsurface drip irrigation	○	○	○	○	○
Steep learning curve	○	○	○	○	○
Market stability (i.e. assurance of processing contracts)	○	○	○	○	○
Insufficient technical assistance	○	○	○	○	○
Irrigation not necessary	○	○	○	○	○

Your Opinion

How important would you find the following policy changes in influencing your decision regarding the adoption of a subsurface drip irrigation system?

Increase in the share supported by the government for the improved irrigation system. Please indicate the necessary governmental cost share if you consider this factor relevant (i.e. 10%).	Type here	Very Important Important Neutral Somewhat Important Not at all Important
Tax credits for the purchase of the new irrigation system. Please indicate the tax percentage reduction, if you consider this factor relevant.	Type here	Very Important Important Neutral Somewhat Important Not at all Important
Payments for reducing greenhouse gas emissions, associated with the adoption of drip irrigation.	Type here	Very Important Important Neutral Somewhat Important Not at all Important
Payments for reducing agro-chemical run-off associated with the adoption of the new irrigation system.	Type here	Very Important Important Neutral Somewhat Important Not at all Important
Increased water use costs, please indicate the rate if this factor is relevant.	Type here	Very Important Important Neutral Somewhat Important Not at all Important
Increased governmental technical assistance and/or information.	Type here	Very Important Important Neutral Somewhat Important Not at all Important

About Subsurface Drip Irrigation

State the level to which you agree or disagree with the following statements.

In the context of your farm the subsurface drip irrigation system could:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Be Profitable	○	○	○	○	○
Be Expensive	○	○	○	○	○
Improve soil conditions	○	○	○	○	○
Reduce fertilizer/chemical run-off	○	○	○	○	○
Reduce production risks	○	○	○	○	○
Reduce water use	○	○	○	○	○
Improve tomato yields	○	○	○	○	○
Be a better alternative than the current one	○	○	○	○	○
Benefit the local community	○	○	○	○	○
Benefit society at large	○	○	○	○	○

Your Opinion

State the level to which you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Farmers should be responsible for minimizing environmental damages coming from their farms.	○	○	○	○	○
Farmers should be the ones supporting the costs associated with environmental damages as a result of their farming.	○	○	○	○	○
Society should share the costs of minimizing agriculture's impacts on the environment.	○	○	○	○	○
Making best use of scarce resources is important to you.	○	○	○	○	○
Cost-share programs supporting the adoption of improved agricultural practices and technologies represent good use of public money.	○	○	○	○	○
Reducing greenhouse gas emissions coming from agriculture is important.	○	○	○	○	○
Reducing water use in agriculture is important.	○	○	○	○	○

About You

What is your relation to the farm?

- Owner
- Manager
- Employee
- Other, please specify Type here

What is your age?

- Under 18
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 or Above
- Prefer Not to Answer

For how many years have you been farming?

Type here

What is the highest level of education you have completed?

- High School
- College
- Technical Degree
- Bachelor's Degree
- Graduate or Professional Degree
- Other, please specify... Type here

What are your main goals as an agricultural producer?

Type here

What are your main motivations for farming?

Type here

Do you belong to any agricultural organization?

- Yes, please specify which ones Type here

- No

What source do you use, when you need information regarding agricultural issues?

- Newsletters
- Agricultural Publications
- Governmental Publications
- Social Media
- Mobile Media
- Internet
- Colleagues/ Neighbours
- Others, Please specify Type here

What percentage of your household's income comes from farming?

- 100%
- 75%
- 50%
- 25%
- Other, please specify Type here

About Your Farm

What is the size of your farm (cultivated acres)?

Type here

How many acres do you allocate to tomato growing?

Type here

Do you operate a livestock enterprise on your farm?

- Yes
- No

Do you use a crop rotation system?

- Yes, please provide details — Type here
- No

In which county is your farm located?

- Essex County
- Chatham-Kent County
- Other, please specify — Type here

What soil type is predominant on your farm?

- Sandy Loam
- Clay Loam
- Other, please specify — Type here

Would you characterize the land on your farm as mostly:

- Flat
- Undulating
- Other, please specify — Type here

How much of your farm land is:

- Owned? — Type here
- Rented/Leased from others? — Type here
- Rented/Leased to others? — Type here
- Other, please specify — Type here

What is the operating arrangement of the farm?

What is the operating arrangement of the farm?

- Sole Proprietorship
- Corporation
- Partnership
- Other, please specify — Type here

What are your average annual gross sales?

- Less than $50,000
- $50,000-$99,000
- $100,000-$249,000
- $250,000-$499,999
- $500,000-$1,000,000
- More than $1,000,000

What percentage of your annual gross sales come from tomatoes?

Type here

Do you have an Environmental Farm Plan?

- Yes
- No

Have you adopted beneficial management practices on your farm, using governmental cost-share programs?

- Yes, please specify how many — Type here
- No

Appendix C. CRONBACH'S ALPHA CALCULATIONS

Internal consistency reliability

factors influencing adoption	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11	f12	f13	f14	f15	Total Score
	5	4	4	4	5	3	5	4	4	4	4	3	3	4	4	60
	5	5	2	3	1	4	5	4	4	4	4	4	3	2	4	54
	5	5	4	3	3	3	5	4	4	4	4	4	4	1	3	56
	4	4	4	4	2	2	3	4	4	4	4	3	3	4	4	53
	5	5	5	5	5	5	5	5	5	5	5	3	4	4	4	70
	5	4	4	3	3	4	4	3	3	5	3	3	3	1	1	49
	5	5	4	5	5	5	5	5	5	4	5	5	5	3	4	70
	5	5	5	5	5	5	5	5	5	5	5	5	5	2	5	72
	4	5	4	4	4	4	5	4	4	4	4	3	3	3	5	60
	5	5	5	5	5	5	5	5	5	5	5	4	4	4	4	71
mean	4.80	4.70	4.10	4.10	3.80	4.00	4.70	4.30	4.30	4.40	4.30	3.70	3.70	2.80	3.80	61.50
standard deviation (s)	0.42	0.48	0.88	0.88	1.48	1.05	0.67	0.67	0.67	0.52	0.67	0.82	0.82	1.23	1.14	8.59
variance (s2)	0.18	0.23	0.77	0.77	2.18	1.11	0.46	0.46	0.46	0.27	0.46	0.68	0.68	1.51	1.29	11.48
k	15															
sum variance	11.48															
sum standard deviation	73.83333															
alpha	0.904869															
cutoff value	0.7	everything above that value has good reliability														

Legend	
Cronbach's alpha	Internal consist
α ≥ 0.9	Excellent
0.9 > α ≥ 0.8	Good
0.8 > α ≥ 0.7	Acceptable
0.7 > α ≥ 0.6	Questionable
0.6 > α ≥ 0.5	Poor
0.5 > α	Unacceptable

barriers to adoption	b1	b2	b3	b4	b5	b6	b7	b8	b9	b10	Total Score
	4	3	3	5	4	5	4	4	3	5	40
	4	2	2	4	5	5	3	3	1	5	34
	4	4	3	3	5	5	5	3	3	3	38
	3	3	3	4	2	4	4	3	3	4	33
	5	5	4	4	5	5	3	5	3	5	44
	3	1	1	1	1	1	5	1	5	1	20
	4	4	4	5	5	5	5	4	4	5	45
	2	3	3	3	4	4	3	3	3	5	33
mean	3.63	3.13	2.88	3.63	3.88	4.25	4.00	3.25	3.13	4.13	35.88
standard deviation (s)	0.92	1.25	0.99	1.30	1.55	1.39	0.93	1.16	1.13	1.46	7.95
variance (s2)	0.84	1.55	0.98	1.70	2.41	1.93	0.86	1.36	1.27	2.13	
k	10										
sumvariance	15.01786										
variance sample	63.26786										
alpha	0.847367										

factors for non adoption	nf1	nf2	nf3	nf4	nf5	nf6	nf7	nf8	nf9	nf10	nf11	nf12	Total Score
	3	3	3	5	5	5	5	5	3	5	5	4	51
	5	5	5	5	5	5	5	3	1	5	1	5	50
	5	5	5	5	5	5	5	5	5	5	3	3	56
	4	4	5	4	4	4	5	4	4	5	4	4	51
	5	3	4	2	4	4	3	3	2	3	3	4	40
	5	4	3	3	4	4	4	1	3	3	1	3	38
	3	3	3	3	3	3	3	3	3	4	3	5	39
	4	5	5	5	5	5	3	5	5	5	5	3	55
	5	3	5	5	4	5	5	3	1	5	1	1	43
	5	3	5	5	4	4	3	2	3	5	2	1	42
	3	3	3	3	1	1	4	1	1	4	1	3	28
	2	1	5	5	3	5	3	4	4	5	4	4	45
	3	3	2	2	3	3	3	3	3	3	3	5	36
	2	1	4	3	4	3	3	1	3	4	3	3	34
	5	3	4	4	2	2	4	3	5	4	4	4	44
	4	4	4	4	5	4	4	3	3	4	3	3	45
	4	2	4	4	4	5	1	2	2	5	2	3	38
	4	4	3	3	3	3	5	4	4	4	4	3	44
	3	3	3	3	1	3	3	3	3	3	3	1	32
	4	4	4	3	5	5	3	4	3	5	3	4	47
	1	2	4	3	3	2	1	2	4	3	1	4	30
	5	3	4	4	2	2	5	4	5	5	5	5	49
	3	1	5	5	2	3	1	1	3	5	3	4	36
	3	3	3	3	3	3	3	2	1	5	2	1	32
	5	5	4	5	2	2	5	1	3	3	3	3	41
	4	3	4	4	3	3	3	4	3	5	3	3	42
	3	1	4	4	3	3	4	1	1	4	1	1	30
	4	3	3	3	3	3	3	3	3	3	3	5	39
	4	3	4	4	4	4	4	4	3	4	3	4	45
mean	3.79	3.10	3.93	3.83	3.41	3.55	3.55	2.90	3.00	4.24	2.83	3.31	41.45
standard deviation (s)	1.08	1.18	0.84	0.97	1.18	1.15	1.21	1.29	1.22	0.83	1.23	1.28	7.48
variance (s2)	1.17	1.38	0.71	0.93	1.39	1.33	1.47	1.67	1.50	0.69	1.50	1.65	
k	12												
sumvariance	15.39901												
variance sample	55.97044												
alpha	0.79077												

255

bmp perceptions	bmp1	bmp2	bmp3	bmp4	bmp5	bmp6	bmp7	bmp8	bmp9	bmp10	Total Score
	4	5	2	3	3	4	3	3	2	3	32
	4	4	4	5	4	5	3	3	3	3	38
	5	3	5	5	5	5	5	5	5	5	48
	4	4	4	4	4	4	4	4	4	4	40
	4	4	3	3	3	4	4	3	3	3	34
	3	5	2	2	4	1	4	2	2	2	27
	4	4	3	4	3	4	3	3	2	2	32
	3	4	3	1	5	1	5	2	1	1	26
	1	5	2	2	2	2	3	2	3	3	25
	4	4	2	4	4	2	4	4	3	4	35
	3	5	2	3	4	4	4	2	2	2	31
	5	5	3	2	4	3	3	2	2	2	31
	4	4	3	3	4	4	4	4	3	3	36
	4	4	4	4	4	4	3	4	3	3	37
	2	5	4	4	4	4	4	4	4	4	39
	5	3	4	2	5	4	5	3	3	3	37
	1	5	3	2	4	4	2	3	3	3	30
	3	4	2	2	3	2	3	3	2	3	27
	4	5	4	3	4	4	4	4	4	4	40
	4	4	3	3	3	3	2	2	2	2	28
	3	5	4	4	4	5	4	4	3	3	39
	4	4	3	3	4	4	5	5	3	3	38
	2	4	3	3	3	5	5	4	4	4	37
	4	4	3	3	4	4	4	4	3	4	37
	5	4	4	5	3	4	4	4	4	3	40
	5	3	5	5	5	5	5	5	5	5	48
	3	3	3	1	1	3	1	3	1	1	20
	4	5	4	5	4	3	4	3	3	3	38
	3	3	2	3	3	3	3	2	3	3	28
	5	4	5	2	5	5	5	5	5	5	46
	2	4	2	4	4	4	3	3	3	3	32
	5	4	2	3	4	4	4	2	2	2	32
	3	4	4	4	3	4	3	2	3	3	33
	4	4	2	5	4	4	3	3	3	4	36
	5	5	4	3	4	4	4	2	3	3	37
	4	4	2	2	4	2	2	2	3	3	28
	4	4	4	3	3	4	3	3	3	3	34
	5	5	4	3	4	4	5	4	5	4	43
	5	5	5	5	5	5	5	5	5	5	50
mean	3.74	4.21	3.26	3.26	3.77	3.69	3.69	3.26	3.08	3.15	35.10
standard deviation (s)	1.09	0.66	0.99	1.14	0.84	1.06	1.00	1.02	1.04	0.99	6.66
variance (s2)	1.20	0.43	0.99	1.30	0.71	1.11	1.01	1.04	1.07	0.98	
k	10										
sumvariance	9.82861										
variance sample	44.305										
alpha	**0.86462**										

general statements on human-env rela	s1	s2	s3	s4	s5	s6	s7	Total Score
	4	2	5	5	5	4	5	30
	4	3	5	5	5	4	5	31
	5	2	5	5	5	5	5	32
	2	2	4	4	4	4	4	24
	4	2	3	5	4	4	4	26
	5	4	3	4	4	2	2	24
	4	2	3	4	4	3	4	24
	4	1	4	4	5	3	3	24
	4	2	4	4	4	3	3	24
	3	3	3	4	3	3	4	23
	4	4	5	4	5	3	4	29
	4	2	5	5	3	4	4	27
	4	3	5	5	5	5	5	32
	4	4	4	4	4	4	4	28
	4	4	3	4	4	4	4	27
	4	2	3	3	4	2	4	22
	4	3	3	3	2	2	2	19
	4	3	3	4	4	4	3	25
	3	2	5	4	5	4	4	27
	4	3	4	2	4	4	4	25
	4	4	4	4	5	4	5	30
	4	3	3	5	5	3	4	27
	4	4	3	4	3	4	4	26
	3	3	5	3	5	3	4	26
	4	2	2	4	3	3	2	20
	5	5	3	5	4	5	5	32
	5	1	4	5	5	3	3	26
	4	3	5	5	4	4	5	30
	2	1	4	4	4	4	4	23
	5	3	5	5	5	5	5	33
	4	4	4	4	4	4	4	28
	5	4	3	4	3	5	5	29
	4	4	4	4	4	3	3	26
	4	3	2	4	2	4	4	23
	5	2	3	5	5	4	5	29
	4	4	4	4	4	5	4	29
	5	3	3	4	4	3	3	25
	5	3	4	4	4	4	4	28
	3	3	4	4	5	5	5	29
mean	4.03	2.87	3.79	4.18	4.13	3.74	3.97	26.72
standard deviation (s)	0.74	0.98	0.89	0.68	0.83	0.85	0.87	3.33
variance (s2)	0.55	0.96	0.80	0.47	0.69	0.72	0.76	
k	7							
sumvariance	4.95277							
variance sample	11.1026							
alpha	0.64623							
if s2 is deleted then cronbach's alpha is 0.732								

Policy Changes	pc1	pc2	pc3	pc4	pc5	pc6	Total Score
	5	5	5	5	5	5	30
	5	5	3	5	5	5	28
	4	5	4	4	3	4	24
	4	4	4	4	2	4	22
	1	1	1	1	3	1	8
	4	4	1	1	1	1	12
	3	3	3	3	3	3	18
	4	4	4	4	4	4	24
	5	5	1	5	1	5	22
	4	3	3	3	4	3	20
	4	2	4	3	3	3	19
	5	5	1	1	1	2	15
	1	3	1	1	5	5	16
	3	3	3	3	3	3	18
	5	4	4	3	3	4	23
	4	4	4	4	4	3	23
	3	3	1	1	3	2	13
	5	5	3	4	4	5	26
	3	3	3	3	3	3	18
	4	3	4	3	3	4	21
	5	1	3	5	3	5	22
	5	5	5	5	4	5	29
	3	3	4	4	3	3	20
	2	2	3	3	3	3	16
	5	5	3	5	3	4	25
	1	3	3	4	3	4	18
	4	4	4	4	5	1	22
	1	3	3	3	1	1	12
	3	4	4	4	3	3	21
mean	3.62	3.59	3.07	3.38	3.14	3.38	20.17
standard deviation (s)	1.35	1.18	1.22	1.32	1.16	1.32	5.24
variance (s2)	1.82	1.39	1.50	1.74	1.34	1.74	
k	6						
sumvariance	9.52956						
variance sample	27.4335						
alpha	0.78316						

Appendix D. COST OF PRODUCTION TOMATOES UNDER BASELINE AND ALTERNATIVE SCENARIOS

Table D.1. Cost of Production Tomatoes under Baseline Scenario – Year 1

Cost of production items (year 1)	Total ($/acre)	Total ($/ha)
Revenue from tomato sales	$4,891.69	$12,087.62
Variable Costs		
Land Preparation		
Primary Tillage - Chisel Plow	$15.41	$38.09
Secondary Tillage - Disk Plow	$15.41	$38.09
Bed Shaping	$10.28	$25.39
Rye Strips Planting	$6.17	$15.24
Fertilizer Application - K	$154.15	$380.91
Mushroom Compost Application	$25.69	$63.49
Soil Testing	$4.20	$10.39
Land Preparation Costs	**$231.32**	**$571.60**
Cultural		
Ripping Tomato Beds	$12.33	$30.47
Weed Control - Roundup/Glyphosate Application	$14.39	$35.55
Pre-seed Bed Formation	$20.55	$50.79
Insect Control - VAPAM Application	$102.77	$253.94
Fertilizer and Micronutrients Application	$282.61	$698.34
Final Bed Preparation	$61.66	$152.36
Weed Control - Roundup/Glyphosate Application	$17.98	$44.44
Tomato Transplants	$400.79	$990.37
Planting labor	$128.46	$317.43
Planter and tractor use	$20.55	$50.79
Fertilizer and Insecticide	$10.28	$25.39
Cultivation	$51.38	$126.97
Weed Control - Herbicides Application	$35.97	$88.88
Disease control - Fungicide Bravo Application	$141.82	$350.44
Fruit Ripener - Ethrel Application	$28.77	$71.10
Cultural Practices Related Costs	**$1,330.31**	**$3,287.27**
Irrigation		
Drip Tape (4mm, Streamline Netafim)	$0.00	$0.00
Install Drip Tape (2hx2ppl@12.5/acre)	$0.00	$0.00
Install Drip Tape (80 hp tractor 26.5L/2h/acre@1.28$/L)	$0.00	$0.00
Retrieve Drip Tape (7 ppl x 0.5h @12.5$/h)	$89.92	$222.20
Retrieve Drip Tape (80 hp tractor 13.25L/h x 0.5h/acre@1.28$/L)	$8.71	$21.53

Drip Tape Disposal	$20.55	$50.79
Connectors	$0.00	$0.00
Manual Valves and Fittings	$0.00	$0.00
Headers	$0.00	$0.00
Other materials	$0.00	$0.00
Install Lateral Line (Header 3"/7.5 cm) (3ppl@12.5$/h x 1h/acre)	$0.00	$0.00
Install Lateral Line (Header 3"/7.5 cm) (13.25$/h x 1h/acre@1.28$/L)	$0.00	$0.00
Retrieve Lateral Line (Header 3"/7.5 cm) (3ppl@12.5$/h x 1h/acre)	$38.54	$95.23
Retrieve Lateral Line (Header 3"/7.5 cm) (13.25$/h x 1h/acre@1.28$/L)	$17.43	$43.07
Maintenance and Repairs	$24.66	$60.95
Irrigation (100 hp tractor 100h over 25 days = 65L @1.28$/L)	$85.50	$211.28
Hired Labour (1 pers x 4h/day x 25 days @12.5$/h)	$23.36	$57.71
Operator Labour (1 pers x 2 h/day x 25 days @ 20$/h)	$18.68	$46.17
Water Cost LADII (1inch of water/acre/week @ 4 weeks irrigation)	$102.77	$253.94
Fertigation	$30.83	$76.18
Water Reservoir Maintenance (150,000 * 5%)	$70.07	$173.14
Other Equipment Maintenance (pump, filter, etc.)	$30.36	$75.03
Irrigation System Winterization/Spring Startup	$25.69	$63.49
Water Permit Renewal	$28.02	$69.25
Irrigation Costs	**$615.11**	**$1,519.96**
Harvesting		
Harvester	$51.38	$126.97
Additional Wagon and Tractor	$51.38	$126.97
Additional Labour	$25.69	$63.49
Hauling	$49.33	$121.89
Equip and Machinery Maint. & Repairs	$283.64	$700.88
Harvesting Costs	**$461.42**	**$1,140.20**
Total Variable Costs	**$2,638.16**	**$6,519.03**
Fixed Costs		
Land Rent	$462.45	$1,142.74
Crop Insurance	$55.49	$137.13
Management	$205.53	$507.88
Depreciation	$69.88	$172.68
Interest Long Term Loans	$49.33	$121.89
Miscellaneous	$61.66	$152.36
Total Fixed Costs	**$904.35**	**$2,234.69**
Total Costs	**$3,542.50**	**$8,753.71**
Net Return	**$1,349.18**	**$3,333.90**

Table D.2. Cost of Production Tomatoes under Alternative Scenario – Year 1

	Total ($/acre)	Total ($/ha)
Revenue from tomato sales	$4,891.69	$12,087.62
Variable Costs		
Land Preparation		
Primary Tillage - Chisel Plow	$15.41	$38.09
Secondary Tillage - Disk Plow	$15.41	$38.09
Bed Shaping	$10.28	$25.39
Rye Strips Planting	$6.17	$15.24
Fertilizer Application - K	$154.15	$380.91
Mushroom Compost Application	$25.69	$63.49
Soil Testing	$4.20	$10.39
Land Preparation Costs	**$231.32**	**$571.60**
Cultural		
Ripping Tomato Beds	$12.33	$30.47
Weed Control - Roundup/Glyphosate Application	$14.39	$35.55
Pre-seed Bed Formation	$20.55	$50.79
Insect Control - VAPAM Application	$102.77	$253.94
Fertilizer and Micronutrients Application	$282.61	$698.34
Final Bed Preparation	$61.66	$152.36
Weed Control - Roundup/Glyphosate Application	$17.98	$44.44
Tomato Transplants	$400.79	$990.37
Planting labor	$128.46	$317.43
Planter and tractor use	$20.55	$50.79
Fertilizer and Insecticide	$10.28	$25.39
Cultivation	$51.38	$126.97
Weed Control - Herbicides Application	$35.97	$88.88
Disease control - Fungicide Bravo Application	$141.82	$350.44
Fruit Ripener - Ethrel Application	$28.77	$71.10
Cultural Costs	**$1,330.31**	**$3,287.27**
Irrigation		
Drip Tape (6-8mm, Streamline Netafim)	$0.00	$0.00
Install Drip Tape (2hx2ppl@12.5/acre)	$0.00	$0.00
Install Drip Tape (80 hp tractor 26.5L/2h/acre@1.28$/L)	$0.00	$0.00
Retrieve Drip Tape (3 ppl/acre/h @12.5$/h)	$0.00	$0.00
Retrieve Drip Tape (80 hp tractor 13.25L/h x 0.5h/acre@1.28$/L)	$0.00	$0.00
Drip Tape Disposal	$0.00	$0.00
Connectors	$0.00	$0.00
Manual Valves and Fittings	$0.00	$0.00

Table D.2. Continued		
Headers	$0.00	$0.00
Other materials	$0.00	$0.00
Install Lateral Line (Header 3"/7.5 cm) (3ppl@12.5$/h x 1h/acre)	$0.00	$0.00
Install Lateral Line (Header 3"/7.5 cm) (13.25$/h x 1h/acre@1.28$/L)	$0.00	$0.00
Retrieve Lateral Line (Header 3"/7.5 cm) (3ppl@12.5$/h x 1h/acre)	$0.00	$0.00
Retrieve Lateral Line (Header 3"/7.5 cm) (13.25$/h x 1h/acre@1.28$/L)	$0.00	$0.00
Maintenance and Repairs	$0.00	$0.00
Irrigation (100 hp tractor 100h over 25 days = 65L @1.28$/L)	$85.50	$211.28
Hired Labour (1 pers x 4h/day x 25 days @12.5$/h)	$23.36	$57.71
Operator Labour (1 pers x 2 h/day x 25 days @ 20$/h)	$18.68	$46.17
Water Cost LADII (1inch of water/acre/week)	$102.77	$253.94
Fertigation	$30.83	$76.18
Water Reservoir Maintenance (150,000 * 5%)	$70.07	$173.14
Other Equipment Maintenance (pump, filter, etc.)	$30.36	$75.03
Irrigation system winterization and startup	$74.51	$184.11
Water Permit Renewal	$0.00	$0.00
Irrigation Costs	**$436.08**	**$1,077.57**
Harvesting		
Harvester	$51.38	$126.97
Additional Wagon and Tractor	$51.38	$126.97
Additional Labour	$25.69	$63.49
Hauling	$49.33	$121.89
Equip and Machinery Maint. & Repairs	$283.64	$700.88
Cultural Costs	$461.42	$1,140.20
Total Variable Costs	**$2,459.13**	**$6,076.64**
Fixed Costs		
Land Rent	$462.45	$1,142.74
Crop Insurance	$55.49	$137.13
Management	$205.53	$507.88
Depreciation	$69.88	$172.68
Interest Long Term Loans	$49.33	$121.89
Miscellaneous	$61.66	$152.36
Total Fixed Costs	**$904.35**	**$2,234.69**
Total Costs	**$3,363.47**	**$8,311.32**
Net Return	**$1,528.21**	**$3,776.30**

Appendix E. COST OF PRODUCTION CRANBERRY UNDER BASELINE SCENARIO

Table E.1. Cost of Production Cranberry Baseline Scenario – Year 1

Cost of Production Items		$/acre	$/ha
Production Revenues			
	Fruit sales revenue	$3,903.37	$9,645.23
	Selling fresh fruit revenue	$491.00	$1,213.26
	Conditioning income	$404.28	$998.99
	Quality premium income	$392.73	$970.43
	Revenue loyalty bonus	$136.75	$337.91
	Fruit drying income	$71.55	$176.80
	Other Revenue	$1,047.62	$2,588.66
Total Revenues		**$6,447.31**	**$15,931.29**
Variable Costs			
	Hired Labour	$658.78	$1,627.86
	Technical Wages	$193.31	$477.68
	Management Wages	$221.73	$547.89
	Transportation	$81.86	$202.28
	Cranberry cleaning fee	$2.18	$5.39
	Pollination	$145.47	$359.46
	Analyses - water, soil and plants	$9.40	$23.24
	Herbicide & other agro-chemicals	$98.10	$242.42
	Fertilizer	$273.28	$675.28
	Snow Removal	$1.15	$2.84
	Sandblasting package	$25.98	$64.20
	Pond care & dikes	$7.24	$17.90
	Tractor Maintenance	$51.70	$127.74
	Rolling stock maintenance	$46.70	$115.39
	Machinery Maintenance	$202.63	$500.71
	Machinery and equipment rental	$24.76	$61.18
	Spending irrigation, fields, etc.	$39.49	$97.57
	Maintenance pumping station	$4.84	$11.96
	Fuel	$299.86	$740.95
	Tools	$8.27	$20.44
	Electricity	$63.34	$156.51
	Potable water	$2.52	$6.24
	Overheads / Supplies	$3.36	$8.31
	Waste disposal costs	$2.70	$6.68
	Misc. Costs	$135.07	$333.75
Total Variable Costs		**$2,603.75**	**$6,433.86**

Table E.1. Continued		
Fixed Costs		
Administration Wages	$334.58	$826.75
Professional Fees	$135.22	$334.12
Interest long term debt	$440.60	$1,088.72
AgriStability	$13.46	$33.27
R & D	$42.97	$106.19
Donations & Sponsorships	$115.78	$286.09
Other costs	$2.35	$5.81
Subtotal Fixed Costs	**$1,084.96**	**$2,680.94**
Amortization Costs		
Buildings	$58.95	$145.68
Pumping Station	$10.79	$26.67
Trims	$9.45	$23.35
Machinery and equipment depreciation	$155.23	$383.57
Ponds and Streams	$142.02	$350.93
Irrigation	$0.96	$2.37
Other	$3.89	$9.61
Subtotal Fixed Costs	**$381.29**	**$942.17**
Total Fixed Costs	**$1,466.25**	**$3,623.11**
Total Revenues	**$6,447.31**	**$15,931.29**
Total Variable Costs	**$2,603.75**	**$6,433.86**
Total Fixed Costs	**$1,466.25**	**$3,623.11**
Gross Margin	**$3,843.56**	**$9,497.43**
Net Margin	**$2,377.30**	**$5,874.32**

Appendix F. COST OF PRODUCTION ONIONS UNDER BASELINE AND ALTERNATIVE SCENARIOS

Table F.1. Cost of Production Onions under Baseline Scenario – Year 1

Cost of production items	$/acre	$/ha
Production Carrots		
Revenue Carrots (en detail)	$5,156.66	$12,742.11
Wholesale discount	$4,898.83	$12,105.00
Variable Costs Carrots		
Raw Materials Inputs		
Seeds ($/1000 seeds)	$496.63	$1,227.17
Cover crops	$25.59	$63.24
Winter soil protection	$12.80	$31.62
Fertilizer	$147.36	$364.13
Herbicides	$110.95	$274.15
Insecticides	$55.91	$138.16
Fungicides	$65.38	$161.55
Subtotal	**$914.62**	**$2,260.03**
Operation Inputs		
Chiesel	$17.25	$42.63
Rotary cutter	$25.60	$63.26
Aerial seeding of cover crops	$1.67	$4.12
Carrot seeds plantation	$38.19	$94.37
Fertilizer application	$2.64	$6.54
Agro-chemical application/ spraying	$33.58	$82.98
Harvesting	$85.99	$212.48
On farm transport - 2 trailers	$67.77	$167.46
Aerial seeding of winter protection crop(on 20% of the production surface)	$0.33	$0.82
Light harrowing winter crop	$0.40	$0.98
Subtotal	**$273.42**	**$675.63**
Marketing		
Storage fees	$64.21	$158.67
Packaging	$1,753.46	$4,332.80
Transportation	$172.88	$427.18
Subtotal	**$1,990.55**	**$4,918.65**
Other Costs		
Hired labor	$292.95	$723.87
General hired labor	$62.24	$153.78
Crop insurance	$81.27	$200.83

Table F.1. Continued			
	Fields screening services	$78.58	$194.17
	Short term loan interest	$45.93	$113.50
Subtotal		**$560.97**	**$1,386.16**
Total Variable Costs Carrots		**$3,739.57**	**$9,240.47**
Production Onions			
	Revenue Onions Sale (en detail)	$4,206.56	$10,394.40
	Wholesale discount	$3,996.23	$9,874.68
Variable Costs Onions			
Raw Materials Inputs			
	Seeds ($/1000 seeds)	$729.22	$1,801.91
	Cover crops	$25.59	$63.24
	Winter soil protection	$12.80	$31.62
	Fertilizer	$164.88	$407.43
	Herbicides	$130.94	$323.55
	Insecticides	$71.35	$176.31
	Fungicides	$158.78	$392.34
Subtotal		**$1,293.57**	**$3,196.40**
Operation Inputs			
	Chiesel	$17.25	$42.63
	Rotary cutter	$13.74	$33.96
	Aerial seeding of cover crops	$1.67	$4.12
	Onion seeds plantation	$38.19	$94.37
	Fertilizer application	$2.64	$6.54
	Mechanical weed control	$9.25	$22.86
	Agro-chemical application/ spraying	$46.27	$114.34
	Swathing	$8.43	$20.83
	Harvesting	$39.82	$98.40
	On farm transport - 2 trailers	$33.94	$83.87
	Aerial seeding of winter protection crop(on 90% of the production surface)	$1.50	$3.70
Subtotal		**$212.71**	**$525.61**
Marketing			
	Storage fees	$24.65	$60.91
	Packaging	$1,068.24	$2,639.63
	Transportation	$143.80	$355.33
Subtotal		**$1,236.70**	**$3,055.88**

Table F.1. Continued		
Other Costs		
Hired labor	$180.73	$446.60
General hired labor	$62.24	$153.78
Crop insurance	$127.08	$314.00
Fields screening services	$78.58	$194.17
Short term loan interest	$65.42	$161.66
Subtotal	**$514.05**	**$1,270.21**
Total Variable Costs Onions	**$3,257.02**	**$8,048.09**
Fixed Costs Carrots and Onions (40 ha)		
Hired labor	$0.00	$0.00
Long term interest	$0.00	$0.00
Net property taxes	$34.72	$85.80
Insurance	$0.00	$0.00
Liability insurance	$0.00	$0.00
Buildings insurance	$38.57	$95.31
Machinery and equipment insurance	$27.02	$66.77
Maintenance and repairs	$0.00	$0.00
Land	$7.95	$19.64
Buildings	$60.69	$149.98
Equipment	$9.37	$23.15
Professional fees	$112.26	$277.39
Electricity, Phone, Internet, etc.	$28.06	$69.35
Miscellaneous	$22.45	$55.48
Total Fixed Costs Before Amortization	**$341.10**	**$842.86**
Amortization Costs Carrots and Onions (40 ha)		
Machinery and Equipment Shed	$21.82	$53.92
Warehouse with refrigerated section	$57.53	$142.17
Machinery and Equipment (10 years)	$374.76	$926.04
Total amortization costs	**$454.12**	**$1,122.13**
Total Costs	**$7,791.80**	**$19,253.55**
Total Variable Cost	**$6,996.58**	**$17,288.56**
Fixed Cost	**$795.22**	**$1,964.99**
Total Revenue	**$8,895.06**	**$21,979.68**
Net Revenue	**$1,103.25**	**$2,726.14**

Table F.2. Cost of Production Onions Alternative Scenario – Year 1

Cost of production items	$/acre	$/ha
Production Carrots		
Revenue Sales Carrots (en detail)	$6,187.99	$15,290.53
Wholesale discount	$5,878.59	$14,526.00
Variable Costs Carrots		
Raw Materials Inputs		
Seeds ($/1000 seeds)	$496.63	$1,227.17
Cover crops	$25.59	$63.24
Winter soil protection	$12.80	$31.62
Fertilizer	$147.36	$364.13
Herbicides	$110.95	$274.15
Insecticides	$55.91	$138.16
Fungicides	$65.38	$161.55
Subtotal	$914.62	$2,260.03
Operation Inputs		
Chiesel	$17.25	$42.63
Rotary cutter	$25.60	$63.26
Aerial seeding of cover crops	$1.67	$4.12
Carrot seeds plantation	$38.19	$94.37
Fertilizer application	$2.64	$6.54
Agro-chemical application/ spraying	$33.58	$82.98
Irrigation (h)	$33.16	$81.93
Harvesting	$85.99	$212.48
On farm transport - 2 trailers	$67.77	$167.46
Aerial seeding of winter protection crop(on 20% of the production surface)	$0.33	$0.82
Light harrowing winter crop	$0.40	$0.98
Subtotal	**$306.58**	**$757.57**
Marketing		
Storage fees	$77.05	$190.40
Packaging	$2,104.15	$5,199.37
Transportation	$207.45	$512.61
Subtotal	$2,388.66	$5,902.38
Other Costs		
Hired labor	$292.95	$723.87
Hired labor irrigation	$9.43	$23.30
Installation and removal of irrigation system	$7.86	$19.41
General hired labor	$62.24	$153.78
Crop insurance	$81.27	$200.83
Fields screening services	$78.58	$194.17

Table F.2. Continued

	Short term loan interest	$45.93	$113.50
Subtotal		**$578.26**	**$1,428.87**
Total Variable Costs Carrots		**$4,188.12**	**$10,348.84**
Production Onions			
	Onions (en detail)	$4,509.85	$11,143.84
	Wholesale discount	$4,284.36	$10,586.64
Variable Costs Onions			
Raw Materials Inputs			
	Seeds ($/1000 seeds)	$729.22	$1,801.91
	Cover crops	$25.59	$63.24
	Winter soil protection	$12.80	$31.62
	Fertilizer	$164.88	$407.43
	Herbicides	$130.94	$323.55
	Insecticides	$71.35	$176.31
	Fungicides	$158.78	$392.34
Subtotal		**$1,293.57**	**$3,196.40**
Operation Inputs			
	Chiesel	$17.25	$42.63
	Rotary cutter	$13.74	$33.96
	Aerial seeding of cover crops	$1.67	$4.12
	Onion seeds plantation	$38.19	$94.37
	Fertilizer application	$2.64	$6.54
	Mechanical weed control	$9.25	$22.86
	Agro-chemical application/ spraying	$46.27	$114.34
	Irrigation (h tractor and pump)	$33.16	$81.93
	Swathing	$8.43	$20.83
	Harvesting	$39.82	$98.40
	On farm transport - 2 trailers	$33.94	$83.87
	Aerial seeding of winter protection crop(on 90% of the production surface)	$1.50	$3.70
Subtotal		**$245.87**	**$607.54**
Marketing			
	Storage fees	$26.43	$65.31
	Packaging	$1,145.26	$2,829.94
	Transportation	$154.17	$380.95
Subtotal		**$1,325.86**	**$3,276.20**

Table F.2. Continued		
Other Costs		
Hired labor	$180.73	$446.60
Hired labor irrigation	$9.43	$23.30
Installation and removal of irrigation system	$7.86	$19.41
General hired labor	$62.24	$153.78
Crop insurance	$127.08	$314.00
Fields screening services	$78.58	$194.17
Short term loan interest	$65.42	$161.66
Subtotal	**$531.33**	**$1,312.92**
Total Variable Costs Onions	**$3,396.63**	**$8,393.07**
Fixed Costs Carrots and Onions (40 ha)		
Hired labor	$0.00	$0.00
Long term interest	$0.00	$0.00
Net property taxes	$34.72	$85.80
Insurance	$0.00	$0.00
Liability insurance	$2.64	$6.52
Buildings insurance	$38.57	$95.31
Machinery and equipment insurance	$29.12	$71.95
Maintenance and repairs	$0.00	$0.00
Land	$7.95	$19.64
Irrigation system	$18.54	$45.82
Buildings	$60.69	$149.98
Equipment	$10.10	$24.95
Professional fees	$112.26	$277.39
Electricity, Phone, Internet, etc.	$28.06	$69.35
Miscellaneous	$22.45	$55.48
Total Fixed Costs Before Amortization	**$365.10**	**$902.17**
Amortization Costs Carrots and Onions (40 ha)		
Machinery and Equipment Shed	$21.82	$53.92
Warehouse with refrigerated section	$57.53	$142.17
Machinery and Equipment (10 years)	$374.76	$926.04
Total amortization costs	**$454.12**	**$1,122.13**
Total Variable Costs	**$7,584.75**	**$18,741.91**
Total Fixed Costs	**$819.22**	**$2,024.30**
Total Costs	**$8,403.97**	**$20,766.22**
Total Revenue	**$10,162.95**	**$25,112.65**
Net Revenue	**$1,758.98**	**$4,346.43**

Appendix G. ABSOLUTE AND RELATIVE FREQUENCIES OF RESPONDENTS FOR STUDY VARIABLES

Table G.1. Absolute and Relative Frequencies of Respondents by Crop Grown (N = 70)

Crop Grown	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Tomato	39	55.7	55.7	55.7
Cranberry	19	27.1	27.1	82.9
Onion	12	17.1	17.1	100.0
Total	**70**	**100.0**	**100.0**	

Table G.2. Absolute and Relative Frequencies of Respondents by Opinion Regarding BMP Adoption (N = 70)

Adoption	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
No	35	50%	50%	50%
Yes	35	50%	50%	100%
Total	**70**	**100%**	**100%**	

Table G.3. Absolute and Relative Frequencies of Respondents Perception of BMP Profitability (N = 70)

Profitable	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Strongly disagree	2	2.86%	2.86%	2.86%
Disagree	3	4.29%	4.29%	7.14%
Neutral	9	12.86%	12.86%	20.00%
Agree	35	50.00%	50.00%	70.00%
Strongly agree	21	30.00%	30.00%	100%
Total	**70**	**100%**	**100%**	

Table G.4. Absolute and Relative Frequencies of Respondents Perception of BMP Expensiveness (N = 70)

Expensive	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Disagree	3	8.57%	8.57%	8.57%
Neutral	9	15.71%	15.71%	24.29%
Agree	35	54.29%	54.29%	78.57%
Strongly agree	21	21.43%	21.43%	100%
Total	**70**	**100%**	**100%**	

Table G.5. Absolute and Relative Frequencies of Respondents Perception of BMP Fertilizer or Chemical Run-off Reduction (N = 70)

Run-off	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Strongly disagree	3	4.29%	4.29%	4.29%
Disagree	10	14.29%	14.29%	18.57%
Neutral	27	38.57%	38.57%	57.14%
Agree	22	31.43%	31.43%	88.57%
Strongly agree	8	11.43%	11.43%	100%
Total	**70**	**100%**	**100%**	

Table G.6. Absolute and Relative Frequencies of Respondents Perception of BMP Reduction of Production Risks (N = 70)

Production Risk	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Strongly disagree	1	1.43%	1.43%	1.43%
Disagree	6	8.57%	8.57%	10.00%
Neutral	23	32.86%	32.86%	42.86%
Agree	32	45.71%	45.71%	88.57%
Strongly agree	8	11.43%	11.43%	100%
Total	**70**	**100%**	**100%**	

Table G.7. Absolute and Relative Frequencies of Respondents Perception of BMP Reduction of Water Use (N = 70)

Water Use	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Strongly disagree	2	2.86%	2.86%	2.86%
Disagree	5	7.14%	7.14%	10.00%
Neutral	11	15.71%	15.71%	25.71%
Agree	41	58.57%	58.57%	84.29%
Strongly agree	11	15.71%	15.71%	100%
Total	**70**	**100%**	**100%**	

Table G.8. Absolute and Relative Frequencies of Respondents Perception of BMP Improvement of Crop Yields (N = 70)

Yields	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Strongly disagree	1	1.43%	1.43%	1.43%
Disagree	4	5.71%	5.71%	7.14%
Neutral	14	20.00%	20.00%	27.14%
Agree	32	45.71%	45.71%	72.86%
Strongly agree	19	27.14%	27.14%	100%
Total	**70**	**100%**	**100%**	

Table G.9. Absolute and Relative Frequencies of Respondents Perception of BMP as a Better Alternative (N = 70)

Profitable	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Disagree	11	15.71%	15.71%	15.71%
Neutral	19	27.14%	27.14%	42.86%
Agree	27	38.57%	38.57%	81.43%
Strongly agree	13	18.57%	18.57%	100%
Total	**70**	**100%**	**100%**	

Table G.10. Absolute and Relative Frequencies of Respondents Perception of BMP Benefiting the Local Community (N = 70)

Profitable	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Strongly disagree	2	2.86%	2.86%	2.86%
Disagree	9	12.86%	12.86%	15.71%
Neutral	44	62.86%	62.86%	78.57%
Agree	9	12.86%	12.86%	91.43%
Strongly agree	6	8.57%	8.57%	100%
Total	**70**	**100%**	**100%**	

Table G.11. Absolute and Relative Frequencies of Respondents Perception of BMP Benefiting Society at Large (N = 70)

Profitable	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Strongly disagree	2	2.86%	2.86%	2.86%
Disagree	7	10.00%	10.00%	12.86%
Neutral	38	54.29%	54.29%	67.14%
Agree	18	25.71%	25.71%	92.86%
Strongly agree	5	7.14%	7.14%	100%
Total	**70**	**100%**	**100%**	

Table G.12. Absolute and Relative Frequencies of Respondents Agreement with “Farmers should be responsible for minimizing environmental damages coming from their farms” (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Strongly disagree	1	1.43%	1.43%	1.43%
Disagree	3	4.29%	4.29%	5.71%
Neutral	5	7.14%	7.14%	12.86%
Agree	42	60.00%	60.00%	72.86%
Strongly agree	19	27.14%	27.14%	100%
Total	**70**	**100%**	**100%**	

Table G.13. Absolute and Relative Frequencies of Respondents Agreement with “Farmers should be the Ones Supporting the Costs Associated with Environmental Damages as a Result of Their Farming” (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Strongly disagree	6	8.57%	8.57%	8.57%
Disagree	19	27.14%	27.14%	35.71%
Neutral	24	34.29%	34.29%	70.00%
Agree	20	28.57%	28.57%	98.57%
Strongly agree	1	1.43%	1.43%	100%
Total	**70**	**100%**	**100%**	

Table G.14. Absolute and Relative Frequencies of Respondents Agreement with "Society Should Share the Costs of Minimizing Agriculture's Impacts on the Environment" (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Disagree	3	4.29%	4.29%	4.29%
Neutral	23	32.86%	32.86%	37.14%
Agree	29	41.43%	41.43%	78.57%
Strongly agree	15	21.43%	21.43%	100%
Total	**70**	**100%**	**100%**	

Table G.15. Absolute and Relative Frequencies of Respondents Agreement with "Making Best Use of Scarce Resources is Important to You" (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Disagree	1	1.43%	1.43%	1.43%
Neutral	6	8.57%	8.57%	10.00%
Agree	37	52.86%	52.86%	62.86%
Strongly agree	26	37.14%	37.14%	100%
Total	**70**	**100%**	**100%**	

Table G.16. Absolute and Relative Frequencies of Respondents Agreement with "Cost-share Programs Supporting the Adoption of Improved Agricultural Practices and Technologies Represent Good Use of Public Money" (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Disagree	2	2.86%	2.86%	2.86%
Neutral	8	11.43%	11.43%	14.29%
Agree	37	52.86%	52.86%	67.14%
Strongly agree	23	32.86%	32.86%	100%
Total	**70**	**100%**	**100%**	

Table G.17. Absolute and Relative Frequencies of Respondents Agreement with "Reducing Greenhouse Gas Emissions Coming from Agriculture is Important" (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Disagree	4	5.71%	5.71%	5.71%
Neutral	17	24.29%	24.29%	30.00%
Agree	35	50.00%	50.00%	80.00%
Strongly agree	14	20.00%	20.00%	100%
Total	**70**	**100%**	**100%**	

Table G.18. Absolute and Relative Frequencies of Respondents Agreement with "Reducing Water Use in Agriculture is Important" (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Disagree	4	5.71%	5.71%	5.71%
Neutral	9	12.86%	12.86%	18.57%
Agree	36	51.43%	51.43%	70.00%
Strongly agree	21	30.00%	30.00%	100%
Total	**70**	**100%**	**100%**	

Table G.19. Absolute and Relative Frequencies of Respondents' Perception of Initial Cost of the System as a Barrier (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Not at all important	3	4.29%	4.29%	4.29%
Somewhat important	6	8.57%	8.57%	12.86%
Neutral	14	20.00%	20.00%	32.86%
Important	29	41.43%	41.43%	74.29%
Very important	18	25.71%	25.71%	100%
Total	**70**	**100%**	**100%**	

Table G.20. Absolute and Relative Frequencies of Respondents Perception of Availability of Investment Capital as a Barrier (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Not at all important	7	10.00%	10.00%	10.00%
Somewhat important	7	10.00%	10.00%	20.00%
Neutral	21	30.00%	30.00%	50.00%
Important	20	28.57%	28.57%	78.57%
Very important	15	21.43%	21.43%	100%
Total	**70**	**100%**	**100%**	

Table G.21. Absolute and Relative Frequencies of Respondents Perception of Risk of Investment as a Barrier (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Not at all important	3	4.29%	4.29%	4.29%
Somewhat important	3	4.29%	4.29%	8.57%
Neutral	26	37.14%	37.14%	45.71%
Important	21	30.00%	30.00%	75.71%
Very important	17	24.29%	24.29%	100%
Total	**70**	**100%**	**100%**	

Table G.22. Absolute and Relative Frequencies of Respondents Perception of Low Commodity Prices as a Barrier (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Not at all important	6	8.57%	8.57%	8.57%
Somewhat important	6	8.57%	8.57%	17.14%
Neutral	13	18.57%	18.57%	35.71%
Important	25	35.71%	35.71%	71.43%
Very important	20	28.57%	28.57%	100%
Total	**70**	**100%**	**100%**	

Table G.23. Absolute and Relative Frequencies of Respondents Perception of Low Profit Margins as a Barrier (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Not at all important	5	7.14%	7.14%	7.14%
Somewhat important	4	5.71%	5.71%	12.86%
Neutral	17	24.29%	24.29%	37.14%
Important	23	32.86%	32.86%	70.00%
Very important	21	30.00%	30.00%	100%
Total	**70**	**100%**	**100%**	

Table G.24. Absolute and Relative Frequencies of Respondents Perception of Steep Learning Curve as a Barrier (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Not at all important	8	11.43%	11.43%	11.43%
Somewhat important	7	10.00%	10.00%	21.43%
Neutral	36	51.43%	51.43%	72.86%
Important	13	18.57%	18.57%	91.43%
Very important	6	8.57%	8.57%	100%
Total	**70**	**100%**	**100%**	

Table G.25. Absolute and Relative Frequencies of Respondents Perception of Steep Learning Curve as a Barrier (N = 70)

Agreement Degree	**Frequency (N)**	**Percent (%)**	**Valid Percentage (%)**	**Cumulative Percent (%)**
Not at all important	5	7.14%	7.14%	7.14%
Somewhat important	2	2.86%	2.86%	10.00%
Neutral	16	22.86%	22.86%	32.86%
Important	22	31.43%	31.43%	64.29%
Very important	25	35.71%	35.71%	100%
Total	**70**	**100%**	**100%**	

Appendix H. CHI-SQUARE TEST OF HOMOGENEITY RESULTS FOR ADOPTION AND MULTIPLE CATEGORICAL VARIABLES

"The chi-square test of homogeneity (r x 2) is used to determine whether two multinomial probability distributions are equal in the population; that is, whether there is a statistically significant difference in the probabilities between two independent groups in terms of a multinomial dependent variable (i.e., a dependent variable with three or more categories). If there are statistically significant differences in probabilities, you can use a post hoc test to determine where the differences in proportions lie between the two groups of your independent variable in terms of the three or more categories of your dependent variable (i.e., in which category of the dependent variable the probabilities are different between Group 1 and Group 2, and what these differences are). To determine which of the two groups of the independent variable differ in terms of the three or more categories of the dependent variable using a post hoc test called the z-test of two proportions**.**"

The assumptions or requirements for chi-square include:

1. Random sampling *(is not required, provided the sample is not biased. However, the best way to insure the sample is not biased is random selection)*

2. Independent observations *– a critical assumption for chi-square is independence of observations*

3. Mutually exclusive row and column variable categories *that include all observations.*

4. Large expected frequencies *(no expected frequency should be less than 1 and no more than 20% of the expected frequencies should be less than 5)*

Whenever the association between categorical variables was significant, Cramer's V measure of strength of association was reported as well. Cramer's V values range from 0 to 1, with values approaching 1 showing stronger dependencies.

In cases where the sample size requirement, for a Chi-Square Test is not met**,** Fisher's exact test can be used instead. Similar to Chi-Square, this test allows to test for association between categorical variables, especially when sample size is small.

The null hypothesis for a chi-square test of homogeneity is:

H_0*: the probability distribution in each independent group is identical in the population*

The alternative hypothesis for the chi-square test of homogeneity is:

H_A*: the probability distribution in each independent group is not identical in the population*

If the *p*-value is $p < .05$, we can conclude that there is strong enough evidence against the null hypothesis and that the probability distributions are not identical. We can accept the alternative hypothesis and reject the null hypothesis.

Test of Homogeneity Results for Crop Type vs. Adoption Factors

Table H.1. Crop Type * Adoption Cross tabulation

			Adoption **No**	**Yes**	**Total**
Crop Type	Tomato	Count	29[a]	10[b]	39
		Expected Count	19.5	19.5	39.0
		% within Crop Type	74.4%	25.6%	100.0%
		% within Adoption	82.9%	28.6%	55.7%
		Adjusted Residual	4.6	-4.6	
	Cranberry	Count	2[a]	17[b]	19
		Expected Count	9.5	9.5	19.0
		% within Crop Type	10.5%	89.5%	100.0%
		% within Adoption	5.7%	48.6%	27.1%
		Adjusted Residual	-4.0	4.0	
	Onion	Count	4[a]	8[a]	12
		Expected Count	6.0	6.0	12.0
		% within Crop Type	33.3%	66.7%	100.0%
		% within Adoption	11.4%	22.9%	17.1%
		Adjusted Residual	-1.3	1.3	
Total		Count	35	35	70
		Expected Count	35.0	35.0	70.0
		% within Crop Type	50.0%	50.0%	100.0%
		% within Adoption	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table H.2. Crop Type * Adoption Chi-Square Tests Summary Statistic

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	22.432a	2	0.000
Likelihood Ratio	24.574	2	0.000
Linear-by-Linear Association	12.848	1	0.000
N of Valid Cases	70		

[a] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 6.00.

Table H.3. Crop Type * Adoption Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	0.566	0.000
	Cramer's V	0.566	0.000
	Contingency Coefficient	0.493	0.000
N of Valid Cases		70	

Test of Homogeneity Results for Age vs. Adoption Factors

Table H.4. Age * Adoption Cross tabulation

			Adoption		Total
			No	Yes	
Age	1	Count	5[a]	8[a]	13
		Expected Count	6.5	6.5	13.0
		% within Age	38.5%	61.5%	100.0%
		% within Adoption	14.3%	22.9%	18.6%
		Adjusted Residual	-0.9	0.9	
	2	Count	19[a]	20[a]	39
		Expected Count	19.5	19.5	39.0
		% within Age	48.7%	51.3%	100.0%
		% within Adoption	54.3%	57.1%	55.7%
		Adjusted Residual	-0.2	0.2	
	3	Count	11[a]	7[a]	18
		Expected Count	9.0	9.0	18.0
		% within Age	61.1%	38.9%	100.0%
		% within Adoption	31.4%	20.0%	25.7%
		Adjusted Residual	1.1	-1.1	
Total		Count	35	35	70
		Expected Count	35.0	35.0	70.0
		% within Age	50.0%	50.0%	100.0%
		% within Adoption	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table H.5. Age*Adoption Chi-Square Tests Summary Statistic

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	1.607[a]	2	0.448
Likelihood Ratio	1.621	2	0.445
Linear-by-Linear Association	1.576	1	0.209
N of Valid Cases	70		

[a.] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 6.50.

Table H.6. Age*Adoption Symmetric Measures

		Value	**Approximate Significance**
Nominal by Nominal	Phi	0.152	0.448
	Cramer's V	0.152	0.448
	Contingency Coefficient	0.150	0.448
N of Valid Cases		70	

Test of Homogeneity Results for Education vs. Adoption Factors

Table H.7. Education * Adoption Cross Tabulation

			Adoption		**Total**
			No	**Yes**	
Education	Low	Count	6[a]	3[a]	9
		Expected Count	4.5	4.5	9.0
		% within Education	66.7%	33.3%	100.0%
		% within Adoption	17.1%	8.6%	12.9%
		Adjusted Residual	1.1	-1.1	
	Mid	Count	21[a]	10[b]	31
		Expected Count	15.5	15.5	31.0
		% within Education	67.7%	32.3%	100.0%
		% within Adoption	60.0%	28.6%	44.3%
		Adjusted Residual	2.6	-2.6	
	High	Count	8[a]	22[b]	30
		Expected Count	15.0	15.0	30.0
		% within Education	26.7%	73.3%	100.0%
		% within Adoption	22.9%	62.9%	42.9%
		Adjusted Residual	-3.4	3.4	
Total		Count	35	35	70
		Expected Count	35.0	35.0	70.0
		% within Education	50.0%	50.0%	100.0%
		% within Adoption	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table H.8. Education * Adoption Chi-Square Tests Summary Statistic

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	11.437a	2	0.003
Likelihood Ratio	11.803	2	0.003
Linear-by-Linear Association	8.712	1	0.003
N of Valid Cases	70		

[a] Two cells (33.3%) have expected count less than 5. The minimum expected count is 4.50.

Table H.9. Education * Adoption Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	0.404	0.003
	Cramer's V	0.404	0.003
	Contingency Coefficient	0.375	0.003
N of Valid Cases		70	

Test of Homogeneity Results for Environmental Farm Plan vs. Adoption Factors

Table H.10. Environmental Farm Plan * Adoption Cross Tabulation

			Adoption No	Yes	Total
Environmental Farm Plan	No	Count	4[a]	2[a]	6
		Expected Count	3.0	3.0	6.0
		% within Environmental Farm Plan	66.7%	33.3%	100.0%
		% within Adoption	11.4%	5.7%	8.6%
		Adjusted Residual	0.9	-0.9	
	Yes	Count	31a	33a	64
		Expected Count	32.0	32.0	64.0
		% within Environmental Farm Plan	48.4%	51.6%	100.0%
		% within Adoption	88.6%	94.3%	91.4%
		Adjusted Residual	-0.9	0.9	
Total		Count	35	35	70
		Expected Count	35.0	35.0	70.0
		% within Environmental Farm Plan	50.0%	50.0%	100.0%
		% within Adoption	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table H.11. Environmental Farm Plan * Adoption Chi-Square Tests Summary Statistic

	Value	**df**	**Asymptotic Significance (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson Chi-Square	0.729[a]	1	0.393		
Continuity Correction[b]	0.182	1	0.669		
Likelihood Ratio	0.742	1	0.389		
Fisher's Exact Test				0.673	0.337
Linear-by-Linear Association	0.719	1	0.397		
N of Valid Cases	70				

[a.] Two cells (50.0%) have expected count less than 5. The minimum expected count is 3.00.

[b.] Computed only for a 2x2 table.

Table H.12. Environmental Farm Plan * Adoption Symmetric Measures

		Value	**Approximate Significance**
Nominal by Nominal	Phi	0.102	0.393
	Cramer's V	0.102	0.393
	Contingency Coefficient	0.102	0.393
N of Valid Cases		70	

Test of Homogeneity Results for Adopted BMP in the Past vs. Adoption Factors

Table H.13. Adopted BMP in the Past * Adoption Cross Tabulation

			Adoption		Total
			No	**Yes**	
Adopted BMP in the past	No	Count	20[a]	22[a]	42
		Expected Count	21.0	21.0	42.0
		% within Adopted BMP in the past	47.6%	52.4%	100.0%
		% within Adoption	57.1%	62.9%	60.0%
		Adjusted Residual	-0.5	0.5	
	Yes	Count	15[a]	13[a]	28
		Expected Count	14.0	14.0	28.0
		% within Adopted BMP in the past	53.6%	46.4%	100.0%
		% within Adoption	42.9%	37.1%	40.0%
		Adjusted Residual	0.5	-0.5	
Total		Count	35	35	70
		Expected Count	35.0	35.0	70.0
		% within Adopted BMP in the past	50.0%	50.0%	100.0%
		% within Adoption	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the .05 level.

Table H.14. Adopted BMP in the Past * Adoption Chi-Square Tests Summary Statistic

	Value	**df**	**Asymptotic Significance (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson Chi-Square	0.238[a]	1	0.626		
Continuity Correction[b]	0.060	1	0.807		
Likelihood Ratio	0.238	1	0.625		
Fisher's Exact Test				0.808	0.404
Linear-by-Linear Association	0.235	1	0.628		
N of Valid Cases	70				

[a.] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 14.00.
[b] Computed only for a 2x2 table

Table H.15. Adopted BMP in the Past * Adoption Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	-0.058	0.626
	Cramer's V	0.058	0.626
	Contingency Coefficient	0.058	0.626
N of Valid Cases		70	

Test of Homogeneity Results for Goals vs. Adoption Factors

Table H.16. Goals * Adoption Cross Tabulation

			Adoption		Total
			No	Yes	
Goals	Financial Only	Count	10[a]	23[b]	33
		Expected Count	16.5	16.5	33.0
		% within Goals	30.3%	69.7%	100.0%
		% within Adoption	28.6%	65.7%	47.1%
		Adjusted Residual	-3.1	3.1	
	Financial and Others	Count	25[a]	12[b]	37
		Expected Count	18.5	18.5	37.0
		% within Goals	67.6%	32.4%	100.0%
		% within Adoption	71.4%	34.3%	52.9%
		Adjusted Residual	3.1	-3.1	
Total		Count	35	35	70
		Expected Count	35.0	35.0	70.0
		% within Goals	50.0%	50.0%	100.0%
		% within Adoption	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the .05 level.

Table H.17. Goals * Adoption Chi-Square Tests Summary Statistic

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	9.689[a]	1	0.002		
Continuity Correction[b]	8.256	1	0.004		
Likelihood Ratio	9.929	1	0.002		
Fisher's Exact Test				0.004	0.002
Linear-by-Linear Association	9.550	1	0.002		
N of Valid Cases	70				

[a] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 16.50.
[b] Computed only for a 2x2 table.

Table H.18. Goals * Adoption Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	-0.372	0.002
	Cramer's V	0.372	0.002
	Contingency Coefficient	0.349	0.002
N of Valid Cases		70	

Test of Homogeneity Results for Motives vs. Adoption Factors

Table H.19. Motives * Adoption Cross Tabulation

			Adoption		
			No	Yes	Total
Motives	Financial Only	Count	4[a]	5[a]	9
		Expected Count	4.5	4.5	9.0
		% within Motives	44.4%	55.6%	100.0%
		% within Adoption	11.4%	14.3%	12.9%
		Adjusted Residual	-0.4	0.4	
	Financial and Others	Count	31[a]	30[a]	61
		Expected Count	30.5	30.5	61.0
		% within Motives	50.8%	49.2%	100.0%
		% within Adoption	88.6%	85.7%	87.1%
		Adjusted Residual	0.4	-0.4	
Total		Count	35	35	70
		Expected Count	35.0	35.0	70.0
		% within Motives	50.0%	50.0%	100.0%
		% within Adoption	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the .05 level.

Table H.20. Motives * Adoption Chi-Square Tests Summary Statistic

	Value	**df**	**Asymptotic Significance (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson Chi-Square	0.128[a]	1	0.721		
Continuity Correction[b]	0.000	1	1.000		
Likelihood Ratio	0.128	1	0.721		
Fisher's Exact Test				1.000	0.500
Linear-by-Linear Association	0.126	1	0.723		
N of Valid Cases	70				

[a] Two cells (50.0%) have expected count less than 5. The minimum expected count is 4.50.
[b] Computed only for a 2x2 table.

Table H.21. Motives * Adoption Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	-.043	.721
	Cramer's V	.043	.721
	Contingency Coefficient	.043	.721
N of Valid Cases		70	

Test of Homogeneity Results for Profitability vs. Adoption Factors

Table H.22. Profitability * Adoption Cross Tabulation

			Adoption		
			No	Yes	Total
Profitable	Strongly Disagree/Disagree	Count	5a	0b	5
		Expected Count	2.5	2.5	5.0
		% within Profitable	100.0%	0.0%	100.0%
		% within Adoption	14.3%	0.0%	7.1%
		Adjusted Residual	2.3	-2.3	
	Neutral	Count	7a	2a	9
		Expected Count	4.5	4.5	9.0
		% within Profitable	77.8%	22.2%	100.0%
		% within Adoption	20.0%	5.7%	12.9%
		Adjusted Residual	1.8	-1.8	
	Agree/Strongly Agree	Count	23a	33b	56
		Expected Count	28.0	28.0	56.0
		% within Profitable	41.1%	58.9%	100.0%
		% within Adoption	65.7%	94.3%	80.0%
		Adjusted Residual	-3.0	3.0	
Total		Count	35	35	70
		Expected Count	35.0	35.0	70.0
		% within Profitable	50.0%	50.0%	100.0%
		% within Adoption	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the .05 level.

Table H.23. Profitability * Adoption Chi-Square Tests Summary Statistic

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	9.563a	2	.008
Likelihood Ratio	11.669	2	.003
Linear-by-Linear Association	9.302	1	.002
N of Valid Cases	70		

[a] Four cells (66.7%) have expected count less than 5. The minimum expected count is 2.50.

Table H.24. Profitability * Adoption Symmetric Measures

		Value	**Approximate Significance**
Nominal by Nominal	Phi	.370	.008
	Cramer's V	.370	.008
	Contingency Coefficient	.347	.008
N of Valid Cases		70	

Test of Homogeneity Results for Expensive vs. Adoption Results

Table H.25. Expensive * Adoption Cross Tabulation

			Adoption		**Total**
			No	**Yes**	
Expensive	Strongly Disagree/Disagree	Count	0[a]	6[b]	6
		Expected Count	3.0	3.0	6.0
		% within Expensive	0.0%	100.0%	100.0%
		% within Adoption	0.0%	17.1%	8.6%
		Adjusted Residual	-2.6	2.6	
	Neutral	Count	4[a]	7[a]	11
		Expected Count	5.5	5.5	11.0
		% within Expensive	36.4%	63.6%	100.0%
		% within Adoption	11.4%	20.0%	15.7%
		Adjusted Residual	-1.0	1.0	
	Agree/Strongly Agree	Count	31[a]	22[b]	53
		Expected Count	26.5	26.5	53.0
		% within Expensive	58.5%	41.5%	100.0%
		% within Adoption	88.6%	62.9%	75.7%
		Adjusted Residual	2.5	-2.5	
Total		Count	35	35	70
		Expected Count	35.0	35.0	70.0
		% within Expensive	50.0%	50.0%	100.0%
		% within Adoption	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table H.26. Expensive * Adoption Chi-Square Tests Summary Statistic

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8.346[a]	2	0.015
Likelihood Ratio	10.682	2	0.005
Linear-by-Linear Association	8.082	1	0.004
N of Valid Cases	70		

[a] Two cells (33.3%) have expected count less than 5. The minimum expected count is 3.00.

Table H.27. Expensive * Adoption Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	0.345	0.015
	Cramer's V	0.345	0.015
	Contingency Coefficient	0.326	0.015
N of Valid Cases		70	

Test of Homogeneity Results for Reduced fertilizer or chemical run-off vs. Adoption Factors

Table H.28. Reduced Fertilizer or Chemical Runoff vs. Adoption Cross Tabulation

			Adoption	
			No	**Yes**
Reduce fertilizer or chemical run-off	Strongly Disagree/Disagree	Count	9[a]	4[a]
		Expected Count	6.5	6.5
		% within Reduce fertilizer or chemical run-off	69.2%	30.8%
		% within Adoption	25.7%	11.4%
		Adjusted Residual	1.5	-1.5
	Neutral	Count	16[a]	11[a]
		Expected Count	13.5	13.5
		% within Reduce fertilizer or chemical run-off	59.3%	40.7%
		% within Adoption	45.7%	31.4%
		Adjusted Residual	1.2	-1.2
	Agree/Strongly Agree	Count	10[a]	20[b]
		Expected Count	15.0	15.0
		% within Reduce fertilizer or chemical run-off	33.3%	66.7%
		% within Adoption	28.6%	57.1%
		Adjusted Residual	-2.4	2.4
Total		Count	35	35
		Expected Count	35.0	35.0
		% within Reduce fertilizer or chemical run-off	50.0%	50.0%
		% within Adoption	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the .05 level.

Table H.29. Reduced Fertilizer or Chemical Runoff vs. Adoption Chi-Square Tests Summary Statistic

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	6.182[a]	2	0.045
Likelihood Ratio	6.303	2	0.043
Linear-by-Linear Association	5.706	1	0.017
N of Valid Cases	70		

[a] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 6.50.

Table H.30. Reduced Fertilizer or Chemical Runoff vs. Adoption Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	.297	.045
	Cramer's V	.297	.045
	Contingency Coefficient	.285	.045
N of Valid Cases		70	

Test of Homogeneity Results for Reduced production risks vs. Adoption Factors

Table H.31. Reduced Production Risks * Adoption Cross tabulation

			Adoption	
			No	Yes
Reduce production risks	Strongly Disagree/Disagree	Count	3[a]	4[a]
		Expected Count	3.5	3.5
		% within Reduce production risks	42.9%	57.1%
		% within Adoption	8.6%	11.4%
		Adjusted Residual	-0.4	0.4
	Neutral	Count	8[a]	15[a]
		Expected Count	11.5	11.5
		% within Reduce production risks	34.8%	65.2%
		% within Adoption	22.9%	42.9%
		Adjusted Residual	-1.8	1.8
	Agree/Strongly Agree	Count	24[a]	16[a]
		Expected Count	20.0	20.0
		% within Reduce production risks	60.0%	40.0%
		% within Adoption	68.6%	45.7%
		Adjusted Residual	1.9	-1.9
Total		Count	35	35
		Expected Count	35.0	35.0
		% within Reduce production risks	50.0%	50.0%
		% within Adoption	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the .05 level.

Table H.32. Reduced Production Risks * Adoption Chi-Square Tests Summary Statistic

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	3.873[a]	2	.144
Likelihood Ratio	3.919	2	.141
Linear-by-Linear Association	2.539	1	.111
N of Valid Cases	70		

[a] Two cells (33.3%) have expected count less than 5. The minimum expected count is 3.50.

Table H.33. Reduced Production Risks * Adoption Symmetric Measures

		Value	**Approximate Significance**
Nominal by Nominal	Phi	0.235	0.144
	Cramer's V	0.235	0.144
	Contingency Coefficient	0.229	0.144
N of Valid Cases		70	

Test of Homogeneity Results for Reduced water use vs. Adoption Factors

Table H.34. Reduced Water Use * Adoption Cross Tabulation

			Adoption	
			No	**Yes**
Reduce water use	Strongly Disagree/Disagree	Count	6[a]	1[b]
		Expected Count	3.5	3.5
		% within Reduce water use	85.7%	14.3%
		% within Adoption	17.1%	2.9%
		Adjusted Residual	2.0	-2.0
	Neutral	Count	5[a]	6[a]
		Expected Count	5.5	5.5
		% within Reduce water use	45.5%	54.5%
		% within Adoption	14.3%	17.1%
		Adjusted Residual	-0.3	0.3
	Agree/Strongly Agree	Count	24[a]	28[a]
		Expected Count	26.0	26.0
		% within Reduce water use	46.2%	53.8%
		% within Adoption	68.6%	80.0%
		Adjusted Residual	-1.1	1.1
Total		Count	35	35
		Expected Count	35.0	35.0
		% within Reduce water use	50.0%	50.0%
		% within Adoption	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the .05 level.

Table H.35. Reduced Water Use * Adoption Chi-Square Tests Summary Statistic

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	3.970[a]	2	.137
Likelihood Ratio	4.361	2	.113
Linear-by-Linear Association	2.655	1	.103
N of Valid Cases	70		

[a] Two cells (33.3%) have expected count less than 5. The minimum expected count is 3.50.

Table H.36. Reduced Water Use * Adoption Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	0.238	.0137
	Cramer's V	0.238	0.137
	Contingency Coefficient	0.232	0.137
N of Valid Cases		70	

Test of Homogeneity Results for Improved crop yields Vs. Adoption

Table H.37. Improved Crop Yields * Adoption Cross Tabulation

			Adoption	
			No	**Yes**
Improve crop yields	Strongly Disagree/Disagree	Count	4[a]	1[a]
		Expected Count	2.5	2.5
		% within Improve crop yields	80.0%	20.0%
		% within Adoption	11.4%	2.9%
		Adjusted Residual	1.4	-1.4
	Neutral	Count	10[a]	4[a]
		Expected Count	7.0	7.0
		% within Improve crop yields	71.4%	28.6%
		% within Adoption	28.6%	11.4%
		Adjusted Residual	1.8	-1.8
	Agree/Strongly Agree	Count	21[a]	30[b]
		Expected Count	25.5	25.5
		% within Improve crop yields	41.2%	58.8%
		% within Adoption	60.0%	85.7%
		Adjusted Residual	-2.4	2.4
Total		Count	35	35
		Expected Count	35.0	35.0
		% within Improve crop yields	50.0%	50.0%
		% within Adoption	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the .05 level.

Table H.38. Improved Crop Yields * Adoption Chi-Square Tests Summary Statistic

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	5.960[a]	2	0.051
Likelihood Ratio	6.181	2	0.045
Linear-by-Linear Association	5.508	1	0.019
N of Valid Cases	70		

[a] Two cells (33.3%) have expected count less than 5. The minimum expected count is 2.50.

Table H.39. Improved Crop Yields * Adoption Symmetric Measures

		Value	**Approximate Significance**
Nominal by Nominal	Phi	.292	.051
	Cramer's V	.292	.051
	Contingency Coefficient	.280	.051
N of Valid Cases		70	

Test of Homogeneity Results for Be a better alternative than the current one vs. Adoption Factors

Table H.40. Be a Better Alternative than the Current one * Adoption Cross Tabulation

			Adoption	
			No	**Yes**
Be a better alternative than the current one	Strongly Disagree/Disagree	Count	10[a]	1[b]
		Expected Count	5.5	5.5
		% within Be a better alternative than the current one	90.9%	9.1%
		% within Adoption	28.6%	2.9%
		Adjusted Residual	3.0	-3.0
	Neutral	Count	15[a]	4[b]
		Expected Count	9.5	9.5
		% within Be a better alternative than the current one	78.9%	21.1%
		% within Adoption	42.9%	11.4%
		Adjusted Residual	3.0	-3.0
	Agree/Strongly Agree	Count	10[a]	30[b]
		Expected Count	20.0	20.0
		% within Be a better alternative than the current one	25.0%	75.0%
		% within Adoption	28.6%	85.7%
		Adjusted Residual	-4.8	4.8
Total		Count	35	35
		Expected Count	35.0	35.0
		% within Be a better alternative than the current one	50.0%	50.0%
		% within Adoption	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the .05 level.

Table H.41. Be a Better Alternative than the Current one * Adoption Chi-Square Tests Summary Statistic

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	23.732a	2	0.000
Likelihood Ratio	25.795	2	0.000
Linear-by-Linear Association	21.264	1	0.000
N of Valid Cases	70		

[a] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 5.50.

Table H.42. Be a Better Alternative than the Current one * Adoption Symmetric Measures

		Value	**Approximate Significance**
Nominal by Nominal	Phi	0.582	0.000
	Cramer's V	0.582	0.000
	Contingency Coefficient	0.503	0.000
N of Valid Cases		70	

Test of Homogeneity Results for Benefit the local community vs. Adoption Factors

Table H.43. Benefit the Local Community * Adoption Cross Tabulation

			Adoption	
			No	Yes
Benefit the local community	Strongly Disagree/Disagree	Count	9[a]	2[b]
		Expected Count	5.5	5.5
		% within Benefit the local community	81.8%	18.2%
		% within Adoption	25.7%	5.7%
		Adjusted Residual	2.3	-2.3
	Neutral	Count	19[a]	25[a]
		Expected Count	22.0	22.0
		% within Benefit the local community	43.2%	56.8%
		% within Adoption	54.3%	71.4%
		Adjusted Residual	-1.5	1.5
	Agree/Strongly Agree	Count	7[a]	8[a]
		Expected Count	7.5	7.5
		% within Benefit the local community	46.7%	53.3%
		% within Adoption	20.0%	22.9%
		Adjusted Residual	-.3	.3
Total		Count	35	35
		Expected Count	35.0	35.0
		% within Benefit the local community	50.0%	50.0%
		% within Adoption	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table H.44. Benefit the Local Community * Adoption Chi-Square Tests Summary Statistic

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	5.339[a]	2	0.069
Likelihood Ratio	5.706	2	0.058
Linear-by-Linear Association	2.448	1	0.118
N of Valid Cases	70		

[a] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 5.50.

Table H.45. Benefit the Local Community * Adoption Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	.276	.069
	Cramer's V	.276	.069
	Contingency Coefficient	.266	.069
N of Valid Cases		70	

Test of Homogeneity Results for Benefits to Society vs. Adoption Factors

Table H.46. Benefit Society at Large * Adoption Cross Tabulation

			Adoption	
			No	Yes
Benefit society at large	Strongly Disagree/Disagree	Count	8[a]	1[b]
		Expected Count	4.5	4.5
		% within Benefit society at large	88.9%	11.1%
		% within Adoption	22.9%	2.9%
		Adjusted Residual	2.5	-2.5
	Neutral	Count	17[a]	21[a]
		Expected Count	19.0	19.0
		% within Benefit society at large	44.7%	55.3%
		% within Adoption	48.6%	60.0%
		Adjusted Residual	-1.0	1.0
	Agree/Strongly Agree	Count	10[a]	13[a]
		Expected Count	11.5	11.5
		% within Benefit society at large	43.5%	56.5%
		% within Adoption	28.6%	37.1%
		Adjusted Residual	-0.8	0.8
Total		Count	35	35
		Expected Count	35.0	35.0
		% within Benefit society at large	50.0%	50.0%
		% within Adoption	100.0%	100.0%

Each subscript letter denotes a subset of Adoption categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table H.47. Benefit Society at Large * Adoption Chi-Square Tests Summary Statistic

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6.257[a]	2	0.044
Likelihood Ratio	7.012	2	0.030
Linear-by-Linear Association	3.376	1	0.066
N of Valid Cases	70		

[a] Two cells (33.3%) have expected count less than 5. The minimum expected count is 4.50.

Table H.48. Benefit Society at Large * Adoption Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	0.299	0.044
	Cramer's V	0.299	0.044
	Contingency Coefficient	0.286	0.044
N of Valid Cases		70	

Appendix I. WILCOXON-MANN-WHITNEY TEST RESULTS

The Mann-Whitney U test is a rank-based nonparametric test that can be used to determine if there are differences between two groups on a continuous or ordinal dependent variable. Performed Mann-Whitney non-parametric test to assess if there are statistically significant differences between farmers in terms of farming experiences, income percentage coming from farm, farm size, crop share and sales share of specific crops. In order to be able to interpret the results of the test, several assumptions need to be met.

In order to determine whether the distribution of scores for both groups of the independent variable (i.e., the distribution of scores for "adopters" and the distribution of scores for "non-adopters" for the independent variable, "gender") have the same shape or a different shape, a visual assessment was performed using histograms. Furthermore, the Levene's Test of homogeneity of variance was used to assess this statistically. Null and alternative hypothesis for Mann-Whitney U test

H_0: the distribution of scores for the two groups are equal

H_A: the distribution of scores for the two groups are not equal

Table I.1. Mean Rank Value for Producers for the Levene's Test

	Adoption	N	Mean Rank	Sum of Ranks
Experience	No	35	43.69	1529.00
	Yes	35	27.31	956.00
	Total	70		
Income	No	35	34.84	1219.50
	Yes	35	36.16	1265.50
	Total	70		
Farm size	No	21	25.21	529.50
	Yes	21	17.79	373.50
	Total	42		
Crop share	No	34	32.87	1117.50
	Yes	33	35.17	1160.50
	Total	67		
Sales share crops	No	35	29.83	1044.00
	Yes	35	41.17	1441.00
	Total	70		
Ratio of crop out of farm	No	21	17.05	358.00
	Yes	21	25.95	545.00
	Total	42		

A Mann-Whitney U test was run to determine if there were differences in farming experience between adopters and non-adopters. Distributions of farming experience for adopters and non-adopters and females were similar, as assessed by visual inspection and by Levene's Test of Homogeneity - the significance of Levene's test is over 0.05, which suggests that the equal variances assumption holds. Mean farming experience was statistically significantly higher in non-adopters than in adopters, $U = 326$, $z = -3.37$, $p = 0.01$. In other words, adopters have less farming experience than non-adopters do.

There was no statistically significant difference between adopters and non-adopters with regard to percentage of income coming from farm activity, $U = 589$, $z = -0.29$, $p = 0.77$. The difference between farm size across the two groups, was statistically significant, with non-adopters having bigger farms than adopters, $U = 142.5$, $z = 1.96$, $p = 0.05$. Adopters have significantly higher shares of sales coming from the crops of interest, compared to non-adopters, $U = 414$, $z = -2.35$, $p = 0.02$. Land ownership is also statistically different between adopters and non-adopters, with adopter having a higher share of land owned, $U = 402.5$, $z = -2.51$, $p = 0.01$.

Table I.2. Result of Test Statistics[a] for the Levene Test of Homogenity

	Experience	Income	Farm size	Crop share	Ownership	Sales share crops	Ratio of crop out of farm
Mann-Whitney U	326.00	589.50	142.50	522.50	402.50	414.00	127.00
Wilcoxon W	956.00	1219.50	373.50	1117.50	1032.50	1044.00	358.00
Z	-3.37	-.291	-1.964	-.485	-2.515	-2.351	-2.362
Asymp. Sig. (2-tailed)	0.001	0.771	0.050	0.628	0.012	0.019	0.018

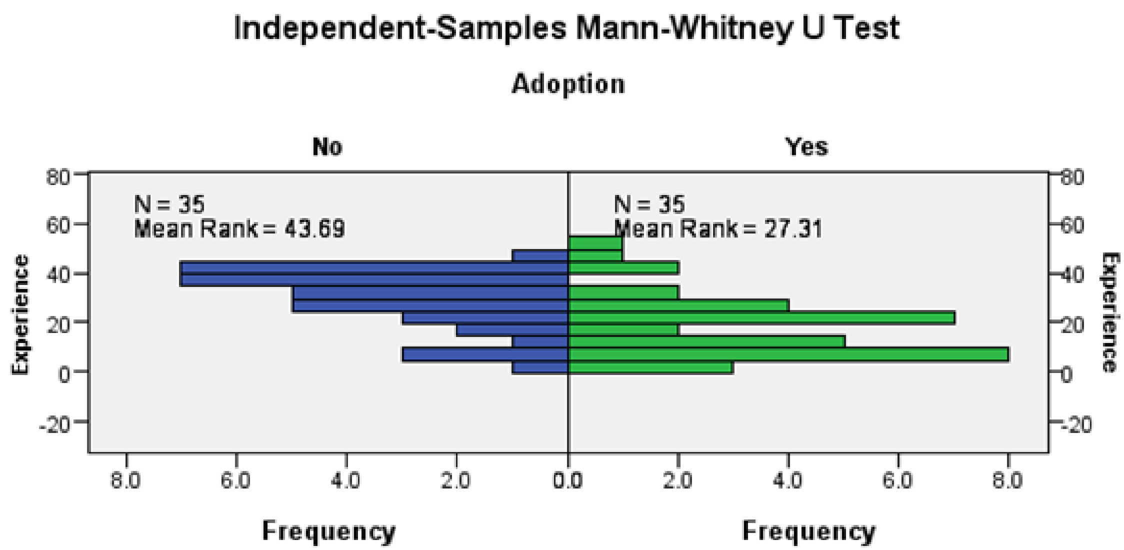
[a]. *Grouping Variable: Adoption*

Table I.3. Summary of Test of Hypothesis for the Equality of Distribution Scores for Factors

Hypothesis Test Summary

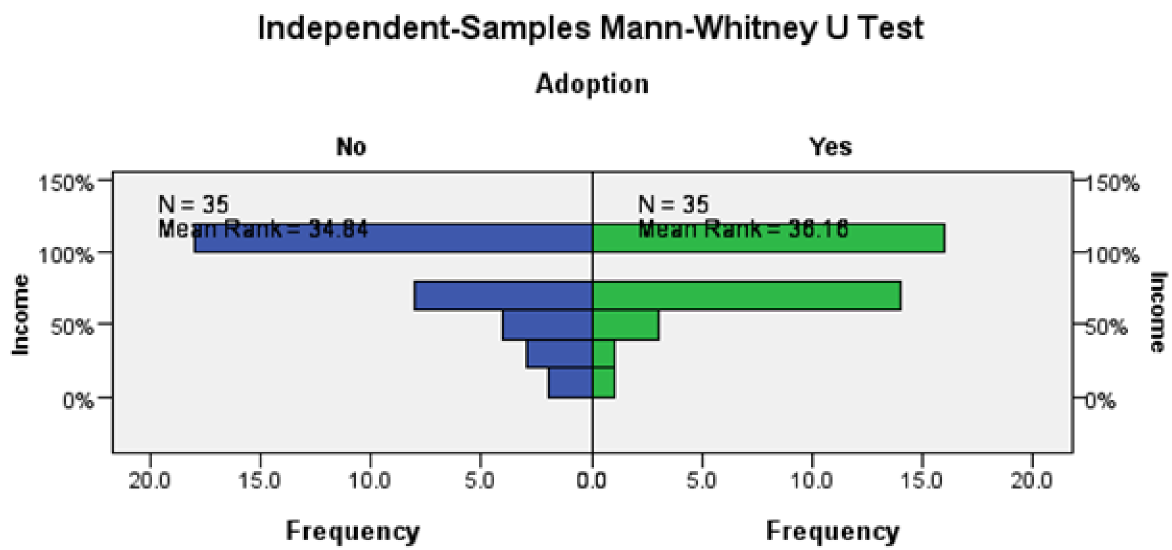
	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Experience is the same across categories of Adoption.	Independent-Samples Mann-Whitney U Test	0.001	Reject the null hypothesis.
2	The distribution of Income is the same across categories of Adoption.	Independent-Samples Mann-Whitney U Test	0.771	Retain the null hypothesis.
3	The distribution of Farm size is the same across categories of Adoption.	Independent-Samples Mann-Whitney U Test	0.050	Reject the null hypothesis.
4	The distribution of Crop share is the same across categories of Adoption.	Independent-Samples Mann-Whitney U Test	0.628	Retain the null hypothesis.
5	The distribution of Ownership is the same across categories of Adoption.	Independent-Samples Mann-Whitney U Test	0.012	Reject the null hypothesis.
6	The distribution of Sales share crops is the same across categories of Adoption.	Independent-Samples Mann-Whitney U Test	0.019	Reject the null hypothesis.
7	The distribution of Ratio of crop out of farm is the same across categories of Adoption.	Independent-Samples Mann-Whitney U Test	0.018	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is 0.05.



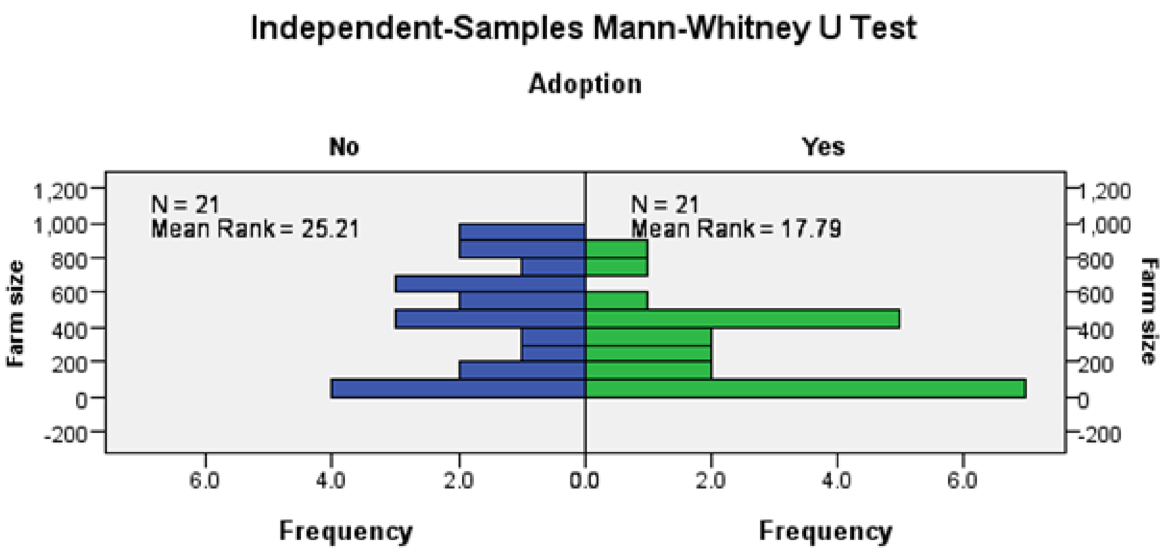
Total N	70
Mann-Whitney U	326.000
Wilcoxon W	956.000
Test Statistic	326.000
Standard Error	84.945
Standardized Test Statistic	-3.373
Asymptotic Sig. (2-sided test)	.001

Figure I.1. Results for the Mann-Whitney Test for the Experience of Producers



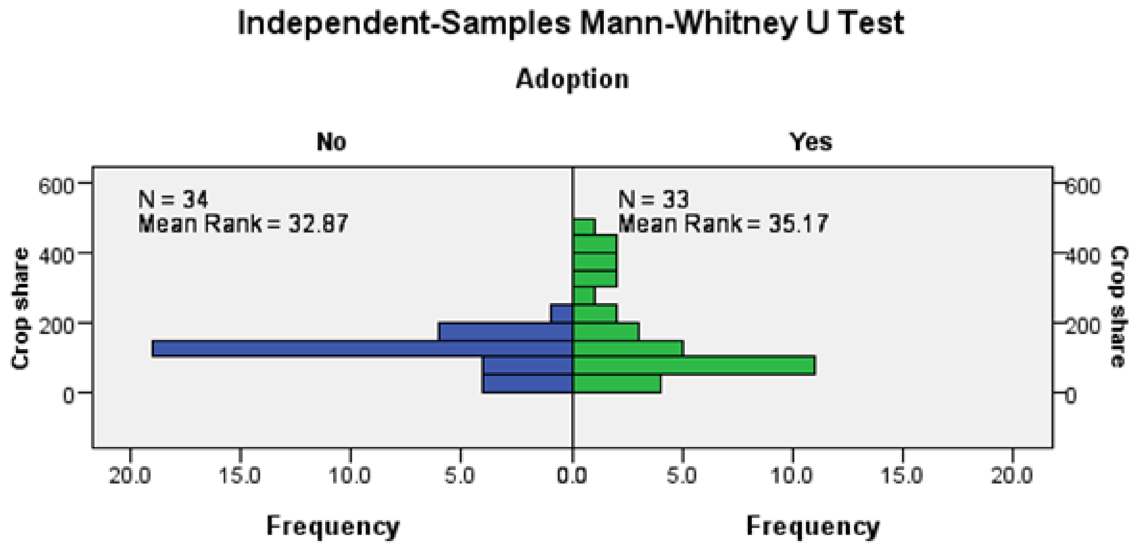
Total N	70
Mann-Whitney U	635.500
Wilcoxon W	1,265.500
Test Statistic	635.500
Standard Error	79.145
Standardized Test Statistic	.291
Asymptotic Sig. (2-sided test)	.771

Figure I.2. Results for the Mann-Whitney Test for the Income Level of Producers



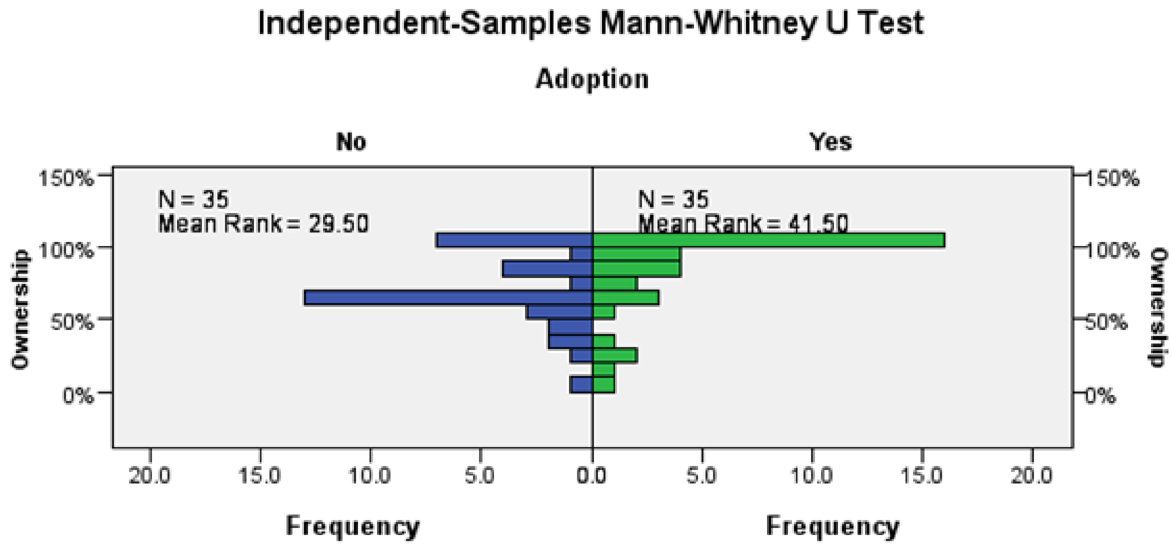
Total N	42
Mann-Whitney U	142.500
Wilcoxon W	373.500
Test Statistic	142.500
Standard Error	39.717
Standardized Test Statistic	-1.964
Asymptotic Sig. (2-sided test)	.050

Figure I.3. Results for the Mann-Whitney Test for the Size of Farm



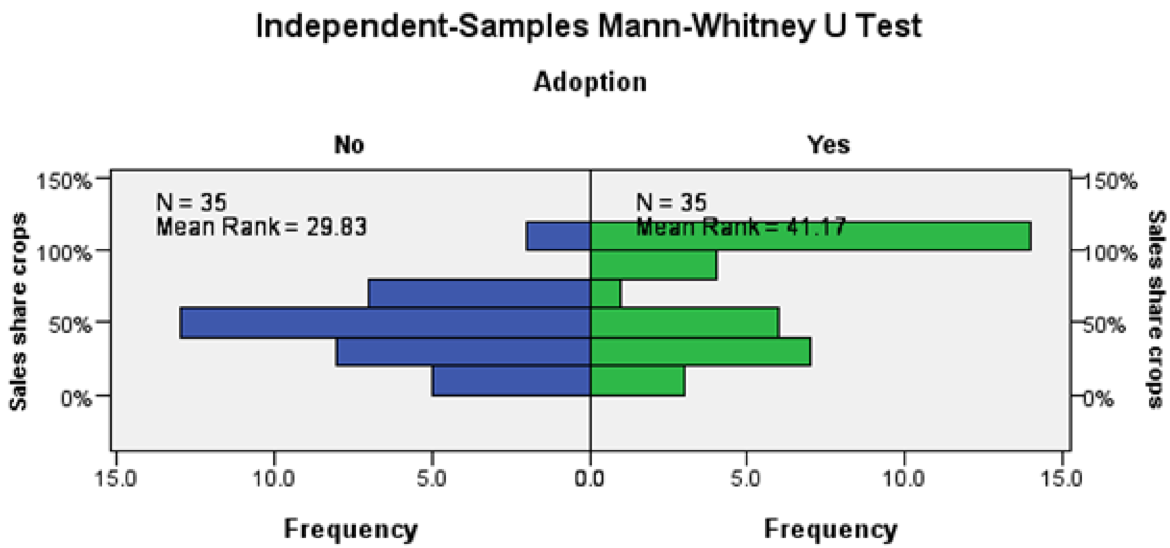
Total N	67
Mann-Whitney U	599.500
Wilcoxon W	1,160.500
Test Statistic	599.500
Standard Error	79.413
Standardized Test Statistic	.485
Asymptotic Sig. (2-sided test)	.628

Figure I.4. Results for the Mann-Whitney Test for the Crop Share on the Farm variable



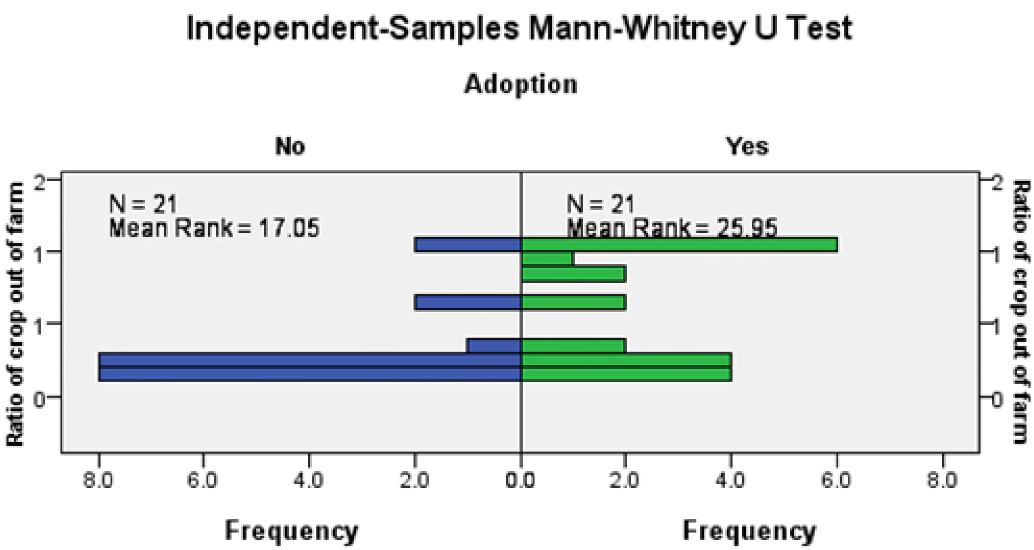
Total N	70
Mann-Whitney U	822.500
Wilcoxon W	1,452.500
Test Statistic	822.500
Standard Error	83.497
Standardized Test Statistic	2.515
Asymptotic Sig. (2-sided test)	.012

Figure I.5. Results for the Mann-Whitney Test for Nature of Ownership of the Farm



Total N	70
Mann-Whitney U	811.000
Wilcoxon W	1,441.000
Test Statistic	811.000
Standard Error	84.428
Standardized Test Statistic	2.351
Asymptotic Sig. (2-sided test)	.019

Figure I.6. Results for the Mann-Whitney Test for Sales Share of Crop Variable



Total N	42
Mann-Whitney U	314.000
Wilcoxon W	545.000
Test Statistic	314.000
Standard Error	39.593
Standardized Test Statistic	2.362
Asymptotic Sig. (2-sided test)	.018

Figure I.7. Results for the Mann-Whitney Test for Ratio of Crop out of Farm Variable

Table I.4. Results for the Levene's Test for Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Experience	Based on Mean	3.408	1	40	0.072
	Based on Median	2.130	1	40	0.152
	Based on Median and with adjusted df	2.130	1	38.926	0.152
	Based on trimmed mean	3.380	1	40	0.073
Income	Based on Mean	4.701	1	40	0.036
	Based on Median	.765	1	40	0.387
	Based on Median and with adjusted df	.765	1	30.029	0.389
	Based on trimmed mean	3.769	1	40	0.059
Farm size	Based on Mean	1.482	1	40	0.231
	Based on Median	1.478	1	40	0.231
	Based on Median and with adjusted df	1.478	1	37.159	0.232
	Based on trimmed mean	1.560	1	40	0.219
Crop share	Based on Mean	3.151	1	40	0.083
	Based on Median	1.822	1	40	0.185
	Based on Median and with adjusted df	1.822	1	31.286	0.187
	Based on trimmed mean	2.444	1	40	0.126
Ownership	Based on Mean	.029	1	40	0.866
	Based on Median	.409	1	40	0.526
	Based on Median and with adjusted df	.409	1	31.338	0.527
	Based on trimmed mean	.209	1	40	0.650
Sales share crops	Based on Mean	.865	1	40	0.358
	Based on Median	.011	1	40	0.916
	Based on Median and with adjusted df	.011	1	30.806	0.916
	Based on trimmed mean	.408	1	40	0.527
Ratio of crop out of farm	Based on Mean	8.835	1	40	0.005
	Based on Median	8.140	1	40	0.007
	Based on Median and with adjusted df	8.140	1	31.442	0.008
	Based on trimmed mean	9.386	1	40	0.004

Note: For distributions to be similar, p value should be >0.05

Table I.5. Descriptive Statistics for Selected Sample Variables for Adopters and Non-adopters

Variable	Adoption Response			Statistic	Std. Error
Experience	No	Mean		25.67	2.918
		95% Confidence Interval for Mean	Lower B.	19.58	
			Upper Bound	31.75	
		5% Trimmed Mean		25.90	
		Median		30.00	
		Variance		178.833	
		Std. Deviation		13.373	
		Minimum		4	
		Maximum		43	
		Range		39	
		Interquartile Range		25	
		Skewness		-0.352	0.501
		Kurtosis		-1.389	0.972
	Yes	Mean		13.90	2.241
		95% Confidence Interval for Mean	Lower B.	9.23	
			Upper Bound	18.58	
		5% Trimmed Mean		13.13	
		Median		11.00	
		Variance		105.490	
		Std. Deviation		10.271	
		Minimum		2	
		Maximum		40	
		Range		38	
		Interquartile Range		15	
		Skewness		0.931	0.501
		Kurtosis		0.542	0.972
Income	No	Mean		72.62%	8.074%
		95% Confidence Interval for Mean	Lower B.	55.78%	
			Upper Bound	89.46%	
		5% Trimmed Mean		75.13%	
		Median		100%	
		Variance		1369.048	
		Std. Deviation		37.001%	
		Minimum		0%	

		Maximum		100%	
		Range		100%	
		Interquartile Range		63%	
		Skewness		-0.945	0.501
		Kurtosis		-0.687	0.972
	Yes	Mean		75.57%	5.984%
		95% Confidence Interval for Mean	Lower B.	63.09%	
			Upper Bound	88.05%	
		5% Trimmed Mean		78.35%	
		Median		79.00%	
		Variance		752.057	
		Std. Deviation		27.424%	
		Minimum		0%	
		Maximum		100%	
		Range		100%	
		Interquartile Range		38%	
		Skewness		-1.325	0.501
		Kurtosis		1.661	0.972
Farm size	No	Mean		448.38	66.579
		95% Confidence Interval for Mean	Lower B.	309.50	
			Upper Bound	587.26	
		5% Trimmed Mean		445.01	
		Median		450.00	
		Variance		93087.048	
		Std. Deviation		305.102	
		Minimum		9	
		Maximum		950	
		Range		941	
		Interquartile Range		589	
		Skewness		.031	0.501
		Kurtosis		-1.216	0.972
	Yes	Mean		279.81	50.850
		95% Confidence Interval for Mean	Lower B.	173.74	
			Upper Bound	385.88	
		5% Trimmed Mean		266.36	
		Median		250.00	

		Variance		54299.662	
		Std. Deviation		233.023	
		Minimum		3	
		Maximum		800	
		Range		797	
		Interquartile Range		330	
		Skewness		0.743	0.501
		Kurtosis		-0.078	0.972
Crop share	No	Mean		95.67	10.610
		95% Confidence Interval for Mean	Lower B.	73.53	
			Upper Bound	117.80	
		5% Trimmed Mean		95.20	
		Median		100.00	
		Variance		2364.233	
		Std. Deviation		48.623	
		Minimum		1	
		Maximum		200	
		Range		199	
		Interquartile Range		44	
		Skewness		-0.083	0.501
		Kurtosis		0.536	0.972
	Yes	Mean		102.24	17.676
		95% Confidence Interval for Mean	Lower B.	65.37	
			Upper Bound	139.11	
		5% Trimmed Mean		94.56	
		Median		80.00	
		Variance		6561.590	
		Std. Deviation		81.004	
		Minimum		1	
		Maximum		345	
		Range		344	
		Interquartile Range		79	
		Skewness		1.655	0.501
		Kurtosis		3.130	0.972
Ownership	No	Mean		65.67%	6.267%
		95% Confidence Interval for Mean	Lower B.	52.59%	

			Upper Bound	78.74%	
		5% Trimmed Mean		66.93%	
		Median		62.00%	
		Variance		824.733	
		Std. Deviation		28.718%	
		Minimum		8%	
		Maximum		100%	
		Range		92%	
		Interquartile Range		58%	
		Skewness		-0.259	0.501
		Kurtosis		-0.892	0.972
	Yes	Mean		82.10%	6.695%
		95% Confidence Interval for Mean	Lower B.	68.13%	
			Upper Bound	96.06%	
		5% Trimmed Mean		85.62%	
		Median		100%	
		Variance		941.190	
		Std. Deviation		30.679%	
		Minimum		0%	
		Maximum		100%	
		Range		100%	
		Interquartile Range		23%	
		Skewness		-1.850	0.501
		Kurtosis		2.328	0.972
Sales share crops	No	Mean		52.45%	5.261%
		95% Confidence Interval for Mean	Lower B.	41.48%	
			Upper Bound	63.43%	
		5% Trimmed Mean		52.29%	
		Median		50.00%	
		Variance		581.298	
		Std. Deviation		24.110%	
		Minimum		8%	
		Maximum		100%	
		Range		93%	
		Interquartile Range		31%	
		Skewness		0.207	0.501

		Kurtosis		0.116	0.972
	Yes	Mean		82.24%	6.086%
		95% Confidence Interval for Mean	Lower B.	69.54%	
			Upper Bound	94.93%	
		5% Trimmed Mean		84.92%	
		Median		100%	
		Variance		777.890	
		Std. Deviation		27.891%	
		Minimum		15%	
		Maximum		100%	
		Range		85%	
		Interquartile Range		41%	
		Skewness		-1.328	0.501
		Kurtosis		0.249	0.972
Ratio of crop out of farm	No	Mean		0.31	0.059
		95% Confidence Interval for Mean	Lower B.	0.19	
			Upper Bound	0.43	
		5% Trimmed Mean		0.28	
		Median		0.20	
		Variance		0.074	
		Std. Deviation		0.272	
		Minimum		0	
		Maximum		1	
		Range		1	
		Interquartile Range		0	
		Skewness		1.834	0.501
		Kurtosis		2.466	0.972
	Yes	Mean		0.57	0.080
		95% Confidence Interval for Mean	Lower B.	0.41	
			Upper Bound	0.74	
		5% Trimmed Mean		0.58	
		Median		0.63	
		Variance		0.134	
		Std. Deviation		0.366	
		Minimum		0	
		Maximum		1	

Range	1	
Interquartile Range	1	
Skewness	0.008	0.501
Kurtosis	-1.872	0.972

Appendix J. CHI-SQUARE TEST OF HOMOGENEITY RESULTS FOR BETTER AND MULTIPLE CATEGORICAL VARIABLES

Test of Homogeneity Results for Age vs. Be a better alternative than the current one Factors

Table J.1. Results of Test of Homogeneity for the Age vs. Be a Better Alternative than the Current One Factors

			Be a better alternative than the current one			
			Strongly Disagree/ Disagree	**Neutral**	**Agree/Strongly Agree**	**Total**
Age	1	Count	1[a]	3[a]	9[a]	13
		Expected Count	2.0	3.5	7.4	13.0
		% within Age	7.7%	23.1%	69.2%	100.0%
		% within Be a better alternative than the current one	9.1%	15.8%	22.5%	18.6%
		Adjusted Residual	-0.9	-0.4	1.0	
	2	Count	8[a]	9[a]	22[a]	39
		Expected Count	6.1	10.6	22.3	39.0
		% within Age	20.5%	23.1%	56.4%	100.0%
		% within Be a better alternative than the current one	72.7%	47.4%	55.0%	55.7%
		Adjusted Residual	1.2	-.9	-.1	
	3	Count	2[a]	7[a]	9[a]	18
		Expected Count	2.8	4.9	10.3	18.0
		% within Age	11.1%	38.9%	50.0%	100.0%
		% within Be a better alternative than the current one	18.2%	36.8%	22.5%	25.7%
		Adjusted Residual	-0.6	1.3	-0.7	
Total		Count	11	19	40	70
		Expected Count	11.0	19.0	40.0	70.0
		% within Age	15.7%	27.1%	57.1%	100.0%
		% within Be a better alternative than the current one	100.0%	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Be a better alternative than the current one categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table J.2. Summary statistics results for the Test of Homogeneity for Age vs. Be a Better Alternative than the Current One Factors

Chi-Square Tests	**Value**	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	3.075[a]	4	0.545
Likelihood Ratio	3.071	4	0.546
Linear-by-Linear Association	0.545	1	0.460
N of Valid Cases	70		

[a] Four cells (44.4%) have expected count less than 5. The minimum expected count is 2.04.

Table J.3. Results of Symmetric Measures for the Test of Homogeneity for the Age vs. Be a Better Alternative than the Current One Factors

		Value	**Approximate Significance**
Nominal by Nominal	Phi	0.210	0.545
	Cramer's V	0.148	0.545
	Contingency Coefficient	0.205	0.545
N of Valid Cases		70	

Test of Homogeneity for the Education * Be a better alternative than the current one Factors

Table J.4. Test of Homogeneity Results for the Education * Be a Better Alternative than the Current One Factors

			Be a better alternative than the current one		
			Strongly Disagree/ Disagree	Neutral	Agree/Strongly Agree
Education	Low	Count	0[a]	3[a]	6[a]
		Expected Count	1.4	2.4	5.1
		% within Education	0.0%	33.3%	66.7%
		% within Be a better alternative than the current one	0.0%	15.8%	15.0%
		Adjusted Residual	-1.4	0.4	0.6
	Mid	Count	7[a]	9[a]	15[a]
		Expected Count	4.9	8.4	17.7
		% within Education	22.6%	29.0%	48.4%
		% within Be a better alternative than the current one	63.6%	47.4%	37.5%
		Adjusted Residual	1.4	.3	-1.3
	High	Count	4[a]	7[a]	19[a]
		Expected Count	4.7	8.1	17.1
		% within Education	13.3%	23.3%	63.3%
		% within Be a better alternative than the current one	36.4%	36.8%	47.5%
		Adjusted Residual	-0.5	-0.6	0.9
Total		Count	11	19	40
		Expected Count	11.0	19.0	40.0
		% within Education	15.7%	27.1%	57.1%
		% within Be a better alternative than the current one	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Be a better alternative than the current one categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table J.5. Chi Square Tests Summary Statistics Results for the Education * Be a Better Alternative than the Current One Factors

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	3.541[a]	4	0.472
Likelihood Ratio	4.856	4	0.302
Linear-by-Linear Association	.005	1	0.944
N of Valid Cases	70		

[a] Four cells (44.4%) have expected count less than 5. The minimum expected count is 1.41.

Table J.6. Measures for the Test of Homogeneity Results for the Education * Be a Better Alternative than the Current One Factors

		Value	**Approximate Significance**
Nominal by Nominal	Phi	.225	.472
	Cramer's V	.159	.472
	Contingency Coefficient	.219	.472
N of Valid Cases		70	

Test of Homogeneity for the Adopted BMP in the past vs. Be a better alternative than the current one Factors

Table J.7. Test of Homogeneity Results for the Adopted BMP in the past vs. Be a Better Alternative than the Current One Factors

			Be a better alternative than the current one		
			Strongly Disagree/ Disagree	**Neutral**	**Agree/ Strongly Agree**
Adopted BMP in the past	No	Count	5[a]	9[a]	28[a]
		Expected Count	6.6	11.4	24.0
		% within Adopted BMP in the past	11.9%	21.4%	66.7%
		% within Be a better alternative than the current one	45.5%	47.4%	70.0%
		Adjusted Residual	-1.1	-1.3	2.0
	Yes	Count	6[a]	10[a]	12[a]
		Expected Count	4.4	7.6	16.0
		% within Adopted BMP in the past	21.4%	35.7%	42.9%
		% within Be a better alternative than the current one	54.5%	52.6%	30.0%
		Adjusted Residual	1.1	1.3	-2.0
Total		Count	11	19	40
		Expected Count	11.0	19.0	40.0
		% within Adopted BMP in the past	15.7%	27.1%	57.1%
		% within Be a better alternative than the current one	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Be a better alternative than the current one categories whose column proportions do not differ significantly from each other at the .05 level.

Table J.8. Chi Square Results for the Adopted BMP in the Past vs. Be a Better Alternative than the Current One Factors

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.900[a]	2	.142
Likelihood Ratio	3.907	2	.142
Linear-by-Linear Association	3.304	1	.069
N of Valid Cases	70		

[a] One cell (16.7%) have expected count less than 5. The minimum expected count is 4.40.

Table J.9. Test of Homogeneity Results for the Adopted BMP in the Past vs. Be a Better Alternative than the Current One Factors

Symmetric Measures		Value	Approximate Significance
Nominal by Nominal	Phi	.236	.142
	Cramer's V	.236	.142
	Contingency Coefficient	.230	.142
N of Valid Cases		70	

Test of Homogeneity for Goals vs. Be a better alternative than the current one Factors

Table J.10. Test of Homogeneity Results for Goals vs. Be a Better Alternative than the Current One Factors

			Be a better alternative than the current one		
			Strongly Disagree / Disagree	**Neutral**	**Agree/ Strongly Agree**
Goals	Financial Only	Count	4[a, b]	4[b]	25[a]
		Expected Count	5.2	9.0	18.9
		% within Goals	12.1%	12.1%	75.8%
		% within Be a better alternative than the current one	36.4%	21.1%	62.5%
		Adjusted Residual	-0.8	-2.7	3.0
	Financial and Others	Count	7[a, b]	15[b]	15[a]
		Expected Count	5.8	10.0	21.1
		% within Goals	18.9%	40.5%	40.5%
		% within Be a better alternative than the current one	63.6%	78.9%	37.5%
		Adjusted Residual	0.8	2.7	-3.0
Total		Count	11	19	40
		Expected Count	11.0	19.0	40.0
		% within Goals	15.7%	27.1%	57.1%
		% within Be a better alternative than the current one	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Be a better alternative than the current one categories whose column proportions do not differ significantly from each other at the .05 level.

Table J.11. Chi Square Results for the Goals vs. Be a Better Alternative than the Current One Factors

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	9.489a	2	.009
Likelihood Ratio	9.909	2	.007
Linear-by-Linear Association	5.450	1	.020
N of Valid Cases	70		

[a] Zero cells (0.0%) have expected count less than 5. The minimum expected count is 5.19

Table J.12. Symmetric Measures Results for the Goals vs. Be a Better Alternative than the Current One Factors

		Value	Approximate Significance
Nominal by Nominal	Phi	0.368	0.009
	Cramer's V	0.368	0.009
	Contingency Coefficient	0.346	0.009
N of Valid Cases		70	

Test of Homogeneity for Motives vs. Be a better alternative than the current one Factors

Table J.13. Test of Homogeneity Results for Motives vs. Be a Better Alternative than the Current One Factors

			Be a better alternative than the current one		
			Strongly Disagree/ Disagree	**Neutral**	**Agree/ Strongly Agree**
Motives	Financial Only	Count	1[a]	2[a]	6[a]
		Expected Count	1.4	2.4	5.1
		% within Motives	11.1%	22.2%	66.7%
		% within Be a better alternative than the current one	9.1%	10.5%	15.0%
		Adjusted Residual	-0.4	-0.4	0.6
	Financial and Others	Count	10[a]	17[a]	34[a]
		Expected Count	9.6	16.6	34.9
		% within Motives	16.4%	27.9%	55.7%
		% within Be a better alternative than the current one	90.9%	89.5%	85.0%
		Adjusted Residual	0.4	0.4	-0.6
Total		Count	11	19	40
		Expected Count	11.0	19.0	40.0
		% within Motives	15.7%	27.1%	57.1%
		% within Be a better alternative than the current one	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Be a better alternative than the current one categories whose column proportions do not differ significantly from each other at the .05 level.

Table J.14. Chi-Square Tests Results for Motives vs. Be a Better Alternative than the Current One Factors

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	0.395[a]	2	0.821
Likelihood Ratio	0.407	2	0.816
Linear-by-Linear Association	0.365	1	0.546
N of Valid Cases	70		

[a] Two cells (33.3%) have expected count less than 5. The minimum expected count is 1.41.

Table J.15. Symmetric Measures Results for the Motives vs. Be a Better Alternative than the Current One Factors

		Value	**Approximate Significance**
Nominal by Nominal	Phi	0.075	0.821
	Cramer's V	0.075	0.821
	Contingency Coefficient	0.075	0.821
N of Valid Cases		70	

Test of Homogeneity for Member of Organizations * Be a better alternative than the current one Factors

Table J.16. Test of Homogeneity Results for Member of Organizations * Be a Better Alternative than the Current One Factors

			Be a better alternative than the current one		
			Strongly Disagree/ Disagree	**Neutral**	**Agree/ Strongly Agree**
Member of Organizations	No	Count	2[a]	7[a]	12[a]
		Expected Count	3.3	5.7	12.0
		% within Member of Organizations	9.5%	33.3%	57.1%
		% within Be a better alternative than the current one	18.2%	36.8%	30.0%
		Adjusted Residual	-0.9	0.8	0.0
	Yes	Count	9[a]	12[a]	28[a]
		Expected Count	7.7	13.3	28.0
		% within Member of Organizations	18.4%	24.5%	57.1%
		% within Be a better alternative than the current one	81.8%	63.2%	70.0%
		Adjusted Residual	0.9	-0.8	0.0
Total		Count	11	19	40
		Expected Count	11.0	19.0	40.0
		% within Member of Organizations	15.7%	27.1%	57.1%
		% within Be a better alternative than the current one	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of ‘Be a better alternative than the current one’ categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table J.17. Chi-Square Tests Results for Member of Organizations * Be a Better Alternative than the Current One Factors

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.155a	2	0.561
Likelihood Ratio	1.213	2	0.545
Linear-by-Linear Association	0.203	1	0.652
N of Valid Cases	70		

[a] One cell (16.7%) have expected count less than 5. The minimum expected count is 3.30.

Table J.18. Symmetric Measures Results for Member of Organizations * Be a Better Alternative than the Current One Factors

		Value	Approximate Significance
Nominal by Nominal	Phi	0.128	0.561
	Cramer's V	0.128	0.561
	Contingency Coefficient	0.127	0.561
N of Valid Cases		70	

Test of Homogeneity for Profitable vs. Be a better alternative than the current one Factors

Table J.19. Test of Homogeneity Results for Profitable vs. Be a Better Alternative than the Current One Factors

			Be a better alternative than the current one		
			Strongly Disagree/ Disagree	**Neutral**	**Agree/ Strongly Agree**
Profitable	Strongly Disagree/Disagree	Count	1[a]	2[a]	2[a]
		Expected Count	.8	1.4	2.9
		% within Profitable	20.0%	40.0%	40.0%
		% within Be a better alternative than the current one	9.1%	10.5%	5.0%
		Adjusted Residual	0.3	0.7	-0.8
	Neutral	Count	5[a]	3[a, b]	1[b]
		Expected Count	1.4	2.4	5.1
		% within Profitable	55.6%	33.3%	11.1%
		% within Be a better alternative than the current one	45.5%	15.8%	2.5%
		Adjusted Residual	3.5	0.4	-3.0
	Agree/Strongly Agree	Count	5[a]	14[a, b]	37b
		Expected Count	8.8	15.2	32.0
		% within Profitable	8.9%	25.0%	66.1%
		% within Be a better alternative than the current one	45.5%	73.7%	92.5%
		Adjusted Residual	-3.1	-0.8	3.0
Total		Count	11	19	40
		Expected Count	11.0	19.0	40.0
		% within Profitable	15.7%	27.1%	57.1%
		% within Be a better alternative than the current one	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Be a better alternative than the current one category whose column proportions do not differ significantly from each other at the .05 level.

Table J.20. Chi-Square Tests Results for Profitable vs. Be a Better Alternative than the Current One Factors

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	15.692[a]	4	0.003
Likelihood Ratio	13.980	4	0.007
Linear-by-Linear Association	7.233	1	0.007
N of Valid Cases	70		

[a] Five cells (55.6%) have expected count less than 5. The minimum expected count is .79.

Table J.21. Symmetric Measures Results for Profitable vs. Be a Better Alternative than the Current One Factors

		Value	**Approximate Significance**
Nominal by Nominal	Phi	0.473	0.003
	Cramer's V	0.335	0.003
	Contingency Coefficient	0.428	0.003
N of Valid Cases		70	

Test of Homogeneity for Expensive vs. Be a better alternative than the current one Factors

Table J.22. Test of Homogeneity Results for Expensive vs. Be A Better Alternative than the Current One Factors

			Be a better alternative than the current one		
			Strongly Disagree/ Disagree	**Neutral**	**Agree/ Strongly Agree**
Expensive	Strongly Disagree/Disagree	Count	0[a]	0[a]	6[a]
		Expected Count	0.9	1.6	3.4
		% within Expensive	0.0%	0.0%	100.0%
		% within Be a better alternative than the current one	0.0%	0.0%	15.0%
		Adjusted Residual	-1.1	-1.6	2.2
	Neutral	Count	1[a]	2[a]	8[a]
		Expected Count	1.7	3.0	6.3
		% within Expensive	9.1%	18.2%	72.7%
		% within Be a better alternative than the current one	9.1%	10.5%	20.0%
		Adjusted Residual	-0.7	-0.7	1.1
	Agree/Strongly Agree	Count	10[a]	17[a]	26[a]
		Expected Count	8.3	14.4	30.3
		% within Expensive	18.9%	32.1%	49.1%
		% within Be a better alternative than the current one	90.9%	89.5%	65.0%
		Adjusted Residual	1.3	1.6	-2.4
Total		Count	11	19	40
		Expected Count	11.0	19.0	40.0
		% within Expensive	15.7%	27.1%	57.1%
		% within Be a better alternative than the current one	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Be a better alternative than the current one categories whose column proportions do not differ significantly from each other at the .05 level.

Table J.23. Chi-Square Tests Results for Expensive vs. Be a Better Alternative than the Current One Factors

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	7.017[a]	4	0.135
Likelihood Ratio	9.278	4	0.055
Linear-by-Linear Association	5.786	1	0.016
N of Valid Cases	70		

[a] Five cells (55.6%) have expected count less than 5. The minimum expected count is .94.

Table J.24. Symmetric Measures Results for Expensive vs. Be a Better Alternative than the Current One Factors

		Value	Approximate Significance
Nominal by Nominal	Phi	0.317	0.135
	Cramer's V	0.224	0.135
	Contingency Coefficient	0.302	0.135
N of Valid Cases		70	

Appendix K. CORRELATION TEST RESULTS FOR ALL ORDINAL AND CONTINUOUS VARIABLES

Table K.1. Estimated Pearson Correlations for Study Variables

		Experience	Income	Crop share	Farm size	Ownership	Sales share crops
Experience	Correlation	1	0.171	0.199	0.397**	-0.188	-0.449**
	Sig. (2-tailed)	--	0.157	0.106	0.009	0.119	0.000
	N	70	70	67	42	70	70
Income	Correlation	0.171	1	0.205	0.316*	0.157	-0.289*
	Sig. (2-tailed)	0.157	--	0.095	0.041	0.193	0.015
	N	70	70	67	42	70	70
Crop share	Correlation	0.199	0.205	1	0.402**	-0.021	-0.217
	Sig. (2-tailed)	0.106	0.095	--	0.008	0.863	0.078
	N	67	67	67	42	67	67
Farm size	Correlation	0.397**	0.316*	0.402**	1	-0.342*	-0.397**
	Sig. (2-tailed)	0.009	0.041	0.008	--	0.027	0.009
	N	42	42	42	42	42	42
Ownership	Correlation	-0.188	0.157	-0.021	-0.342*	1	0.114
	Sig. (2-tailed)	0.119	0.193	0.863	0.027	--	0.349
	N	70	70	67	42	70	70
Sales share crops	Correlation	-0.449**	-0.289*	-0.217	-0.397**	0.114	1
	Sig. (2-tailed)	0.000	0.015	0.078	0.009	0.349	--
	N	70	70	67	42	70	70

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table K.2. Results for the Kendall's Tau Test and Spearman's Rho for Correlations

			Experience	**Income**	**Crop share**	**Farm size**	**Owner-ship**	**Sales share crops**
Kendall's tau_b	Experience	Correlation Coefficient	1.000	0.111	0.205*	0.301**	-0.196*	-0.243**
		Sig. (2-tailed)	--	0.237	0.019	0.006	0.025	0.005
		N	70	70	67	42	70	70
	Income	Correlation Coefficient	0.111	1.000	0.148	0.224	0.035	-0.161
		Sig. (2-tailed)	0.237	--	0.122	0.059	0.713	0.091
		N	70	70	67	42	70	70
	Crop share	Correlation Coefficient	0.205*	0.148	1.000	0.440**	-0.071	-0.167
		Sig. (2-tailed)	0.019	0.122	--	0.000	0.425	0.059
		N	67	67	67	42	67	67
	Farm size	Correlation Coefficient	0.301**	0.224	0.440**	1.000	-.331**	-.329**
		Sig. (2-tailed)	0.006	0.059	0.000	--	.004	.004
		N	42	42	42	42	42	42
	Ownership	Correlation Coefficient	-0.196*	0.035	-0.071	-0.331**	1.000	0.110
		Sig. (2-tailed)	0.025	0.713	0.425	0.004	--	0.216
		N	70	70	67	42	70	70
	Sales share crops	Correlation Coefficient	-0.243**	-0.161	-0.167	-0.33**	0.110	1.000
		Sig. (2-tailed)	0.005	0.091	0.059	0.004	0.216	--
		N	70	70	67	42	70	70
Spearman's rho	Experience	Correlation Coefficient	1.000	0.143	0.269*	0.451**	-0.251*	-0.383**
		Sig. (2-tailed)	--	0.239	0.028	0.003	0.036	0.001
		N	70	70	67	42	70	70
	Income	Correlation Coefficient	0.143	1.000	0.201	0.293	0.045	-0.202
		Sig. (2-tailed)	0.239	--	0.102	0.060	0.714	0.094
		N	70	70	67	42	70	70
	Crop share	Correlation Coefficient	0.269*	0.201	1.000	0.585**	-0.119	-0.217

	Sig. (2-tailed)	0.028	0.102	--	0.000	0.337	0.078
	N	67	67	67	42	67	67
Farm size	Correlation Coefficient	0.451**	0.293	0.585**	1.000	-0.478**	-0.376*
	Sig. (2-tailed)	0.003	0.060	0.000	--	0.001	0.014
	N	42	42	42	42	42	42
Ownership	Correlation Coefficient	-0.251*	0.045	-0.119	-0.478**	1.000	0.178
	Sig. (2-tailed)	0.036	0.714	0.337	0.001	--	0.141
	N	70	70	67	42	70	70
Sales share crops	Correlation Coefficient	-0.383**	-0.202	-0.217	-0.376*	0.178	1.000
	Sig. (2-tailed)	0.001	0.094	0.078	0.014	0.141	--
	N	70	70	67	42	70	70

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table K.3. Value of Spearman’s Rho Vales for Selected factors

			Better alternative than the current one
Spearman's rho	Better alternative than the current one	Correlation Coefficient	1.000
		Sig. (2-tailed)	--
		N	70
	Profitable	Correlation Coefficient	0.477**
		Sig. (2-tailed)	0.000
		N	70
	Expensive	Correlation Coefficient	0.393**
		Sig. (2-tailed)	0.001
		N	70
	Reduce fertilizer or chemical run-off	Correlation Coefficient	0.387**
		Sig. (2-tailed)	0.001
		N	70
	Reduce production risks	Correlation Coefficient	0.117
		Sig. (2-tailed)	0.335
		N	70
	Reduce water use	Correlation Coefficient	0.417**
		Sig. (2-tailed)	0.000
		N	70
	Improve crop yields	Correlation Coefficient	0.553**
		Sig. (2-tailed)	0.000
		N	70
	Benefit local community	Correlation Coefficient	0.594**
		Sig. (2-tailed)	0.000
		N	70
	Benefit society at large	Correlation Coefficient	0.651**
		Sig. (2-tailed)	0.000

	N	70
Farmers should be responsible for minimizing environmental damages coming from their farms.	Correlation Coefficient	0.067
	Sig. (2-tailed)	0.582
	N	70
Farmers should be the ones supporting the costs associated with environmental damages as a result of their farming.	Correlation Coefficient	0.021
	Sig. (2-tailed)	0.862
	N	70
Society should share the costs of minimizing agriculture's impacts on the environment.	Correlation Coefficient	0.065
	Sig. (2-tailed)	0.596
	N	70
Making best use of scarce resources is important to you.	Correlation Coefficient	0.283*
	Sig. (2-tailed)	0.017
	N	70
Cost-share programs supporting the adoption of improved agricultural practices and technologies represent good use of public money.	Correlation Coefficient	0.203
	Sig. (2-tailed)	0.091
	N	70
Reducing greenhouse gas emissions coming from agriculture is important.	Correlation Coefficient	0.346**
	Sig. (2-tailed)	0.003
	N	70
Reducing water use in agriculture is important.	Correlation Coefficient	0.352**
	Sig. (2-tailed)	0.003
	N	70
Experience	Correlation Coefficient	-0.218
	Sig. (2-tailed)	0.070
	N	70
Income	Correlation Coefficient	0.195
	Sig. (2-tailed)	0.106
	N	70

	Farm size	Correlation Coefficient	-0.252
		Sig. (2-tailed)	0.107
		N	42
	Crop share	Correlation Coefficient	-0.015
		Sig. (2-tailed)	0.904
		N	67
	Ownership	Correlation Coefficient	0.252*
		Sig. (2-tailed)	0.035
		N	70
	Sales share crops	Correlation Coefficient	0.132
		Sig. (2-tailed)	0.277
		N	70
	Ratio of crop out of farm	Correlation Coefficient	0.280
		Sig. (2-tailed)	0.073
		N	42

Appendix L. STANDARDIZED RESIDUALS, COOK'S DISTANCE AND PREGIBON's LEVERAGE PLOTS FOR MODELS

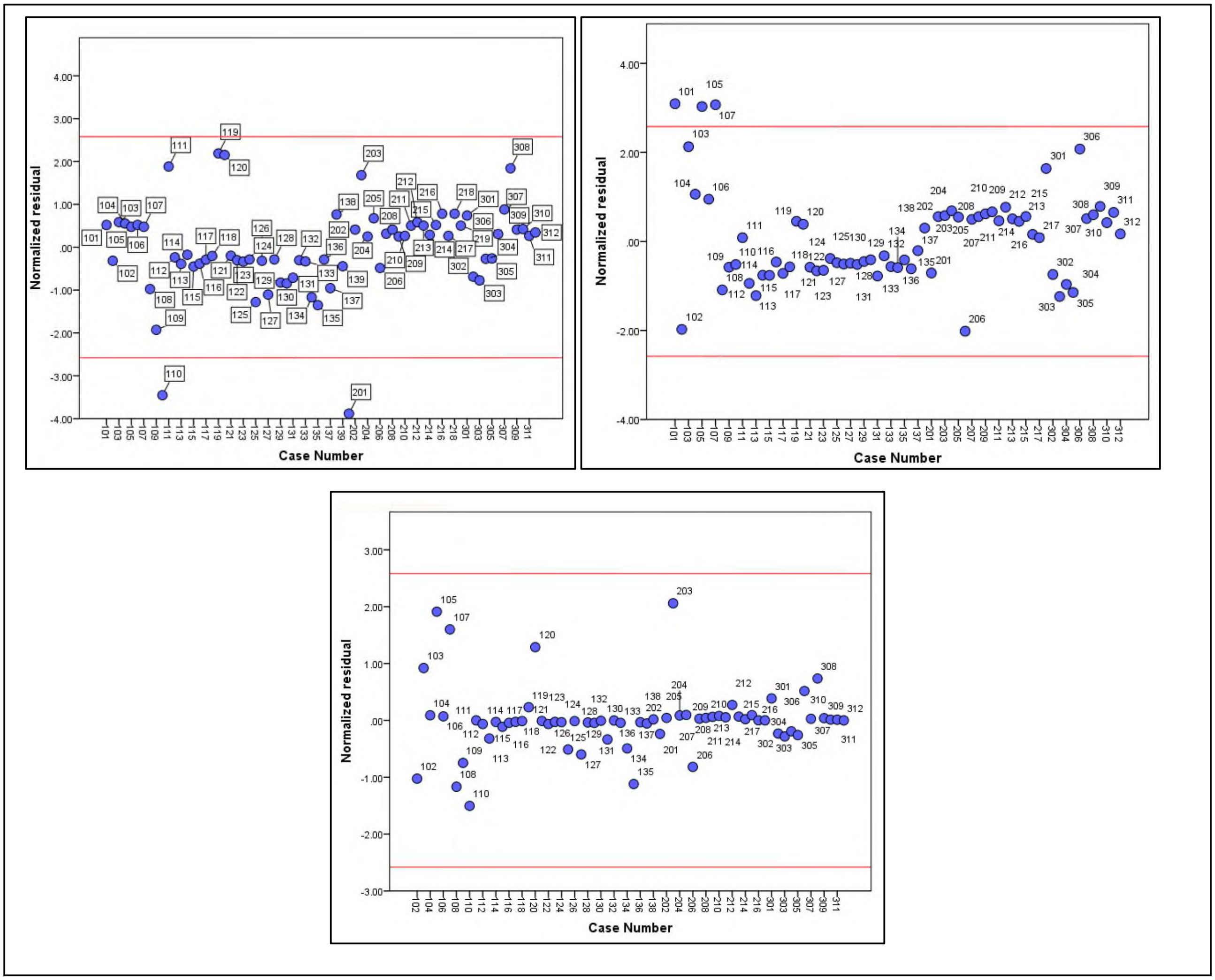


Figure L.1. Standardized Residuals Plots for Models 1 (Top Left), 2 (Top Right) and 3 (Bottom)

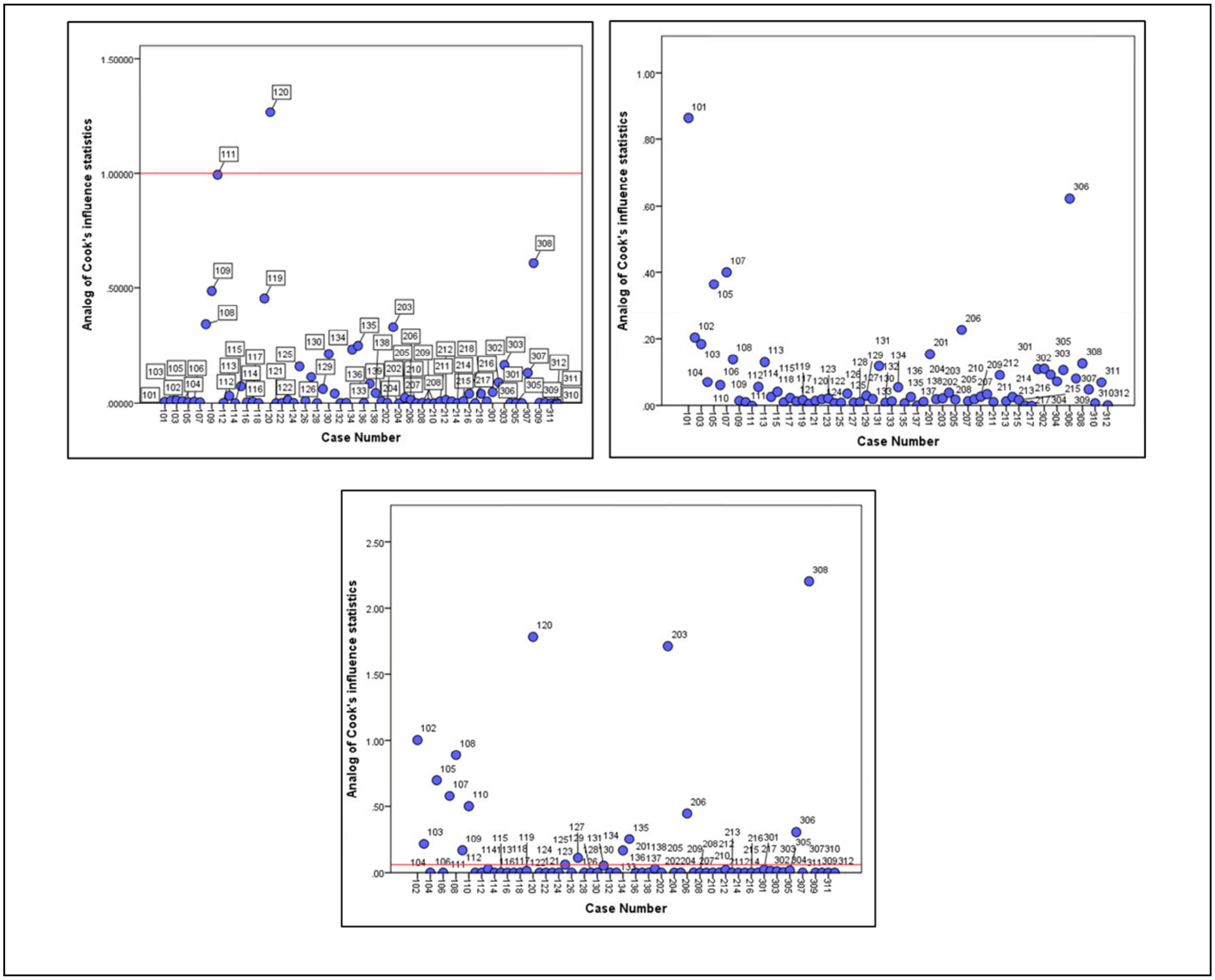


Figure L.2. Cook's Distance Plots for Models 1 (Top Left), 2 (Top Right) and 3 (Bottom)

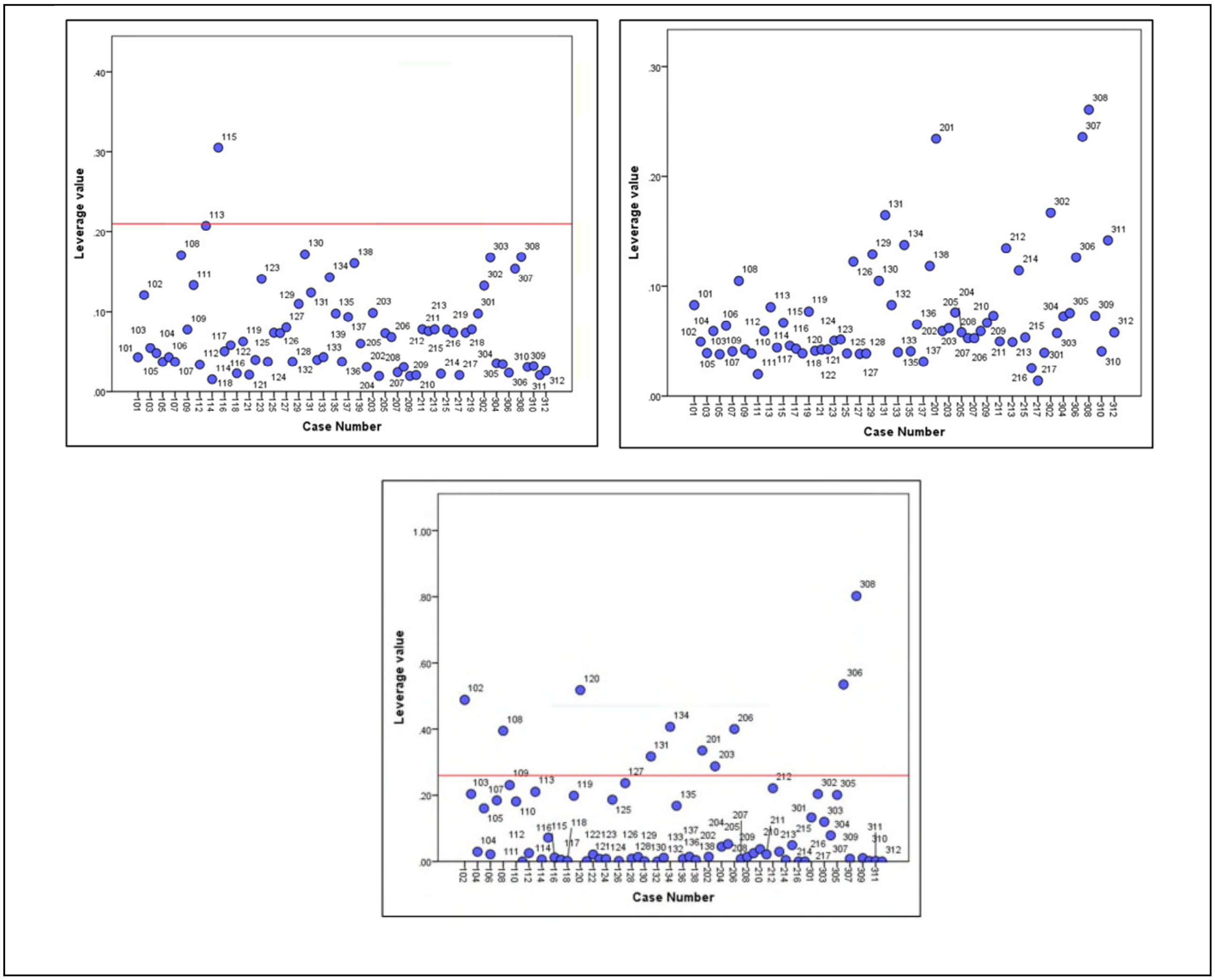


Figure L.3. Pregibon's Leverage Plots for Models 1 (top left), 2 (top right) and 3 (bottom)